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SCIENCE FOR TECHNOLOGY FOR DEVELOPMENT:

An Expanded Programme of Scientific Co-operation in the Commonwealth

Report of the Expert Group

BACKGROUND PAPERS

COMMONWEALTH SCIENCE COUNCIL

COMMONWEALTH SECRETARIAT

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REPORT OF THE EXPERT GROUP: BACKGROUND PAPERS

COMMONWEALTH SCIENCE COUNCIL
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December 1984

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RATIONALE FOR AN EXPANDED PROGRAMME OF SCIENTIFIC COOPERATION IN THE COMMONWEALTH

Theme: APPLICATION OF SCIENCE TO TECHNOLOGICAL DEVELOPMENT

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(A) INTRODUCTION

1. Science plays a major role in most aspects of a modern life-style, and should therefore form the foundation of a nation's socio-economic development. The most commercially powerful nations are those with the most highly developed scientific base, encompassing both the culture and practice of science. The linkage between culture and science is a complementary one.

2. In the context of the Third World, the option of technology transfer, involving the implantation of ready-made solutions from the industrialised world, appears to offer immediate relief from the problems of poverty. However, the relief is generally only effective in the short-term. Thus, the developing society becomes dependant on successive injections of technology from the industrialised world.

3. Given the large and widening disparity between the developing and industrialised worlds' scientific capabilities, it follows that much of the innovation would continue to emanate from the industrialised world, and be adapted for application in the developing world. Even so, it is only those developing countries with effective indigenous scientific capabilities who can obtain the most from technology.

4. In order to address this central problem of development, there is a need for the Commonwealth Science Council to assist its developing member countries to generate an atmosphere that is conducive to the advancement and dissemination of science and technology of the best quality and applicability, thereby facilitating sustainable development. This is akin to the founding of the Royal Society of London when England was a developing economy.

5. The Commonwealth Science Council has emphasized the promotion of science for application to technology for development in its future programme activities. It entails giving consideration to special programmes relevant to small island states, and to the encouragement of a fuller Commmonwealth participation in its programme activities.

6. The emphasis on "Science for Technology for Development" implies the enhancement of professional scientific and technological expertise through:

   (a) scientific research and technological development,
   (b) training and education, and
   (c) information dissemination,

on issues pertinent to development in the various Commonwealth countries. Such an emphasis demands the expansion of cooperative scientific programmes within the Commonwealth.

7. The fulfilment of this objective of enhancing indigenous scientific and technological capability through supportive programme activities, is contingent on two main factors:

   (a) the availability of human resources, sufficiently motivated for embarking in research and training, and establishing collaborative networks on specific projects, and

   (b) the availability of sufficient funds for financing research and training projects, information dissemination, institution building, and programme coordination.

(B) ANALYSIS AND INTERPRETATION

(a) Emphasis on the application of science to development

8. The importance of science for technological development has been realised by both the industrialised and the developing countries:

"Revitalization and growth of the world economy will depend not only on our own efforts but, also to a large extent, upon cooperation among our countries and with other countries in the exploitation of scientific and technological development. We have to exploit the immense opportunities presented by the new technologies, particularly for creating new employment. Our countries will need to train men and women in new technologies, and to create the economic, social and cultural conditions which allow these technologies to develop and flourish ..... " (Versailles Declaration, June 1982)

"Nevertheless, much remains to be done to harness the resources of science to the needs of the developing countries. We should continue our efforts to make training opportunities available to scientists and engineers from the developing countries in our universities, government laboratories and industries. In our universities and laboratories, there are already hundreds of thousands of students and post-doctoral candidates from the developing world taking advantage of these opportunities.

The question of ensuring favourable conditions for the return of these researchers to their countries of origin, and their re-insertion into their countries' professional life must be given very careful attention by the developing countries as well as ourselves. It is important that the developing countries create their own scientific and technological capacities so that each can determine its own socio-economic and cultural path." (Command 8818, "Technology, Growth and Employment", Economic Summit Meeting of 1982)

"Science and technology are not panaceas. They are only one of the means of promoting development. It is the responsiblity of the developing countries themselves to make their choices, and the necessary adaptations to the technologies they create or import. But increased efforts are needed by our governments to understand the problems faced by developing countries in the development and exploitation of technology." (Command 8818, "Technology, Growth and Employment", Economic Summit Meeting of 1982)

"The Heads of State or Government underscored the importance of strengthening the scientific and technological capacities of the developing countries as an important means of promoting their development." (Non-Aligned Movement's Declaration, New Delhi, March 1983)

If these statements or declarations are to be realised through Council's programmes, then member countries need to give science a much higher priority and visibility than before in terms of investments in financial resources, institutional infrastructure and human resources, especially in the developing countries. This recognition is contingent on the availability of individually good scientists and on an infrastructure of a spectrum of associations for ensuring the livelihood of the scientific enterprise.

9. Council's programme emphasis on the application of science to technology needs to address critical issues pertaining to the development of member countries, especially so that:

   (a) they may understand and measure their problems;

   (b) they may optimally use their local resources in solving these problems;

   (c) they may formulate plans and take initiatives in order to seek and obtain the most appropriate external technical and financial assistance for solving these problems;

   (d) they may collaborate effectively with other nations on terms of mutual respect, regardless of level of industrialisation, for solving national and regional problems; and

   (e) they may evaluate the effectiveness of their policies and the action taken to implement those policies.

10. The process of development involves three distinct, sequential and overlapping phases which aim to satisfy both intrinsic and extrinsic human needs:

   (a) the direct satisfaction of basic physiological needs, eg food, health, shelter and education;

   (b) improvements in the quality of life through the economic benefits of manufacturing and trading value-added products; and

   (c) catering for improvement, recreational and leisure needs.

   The first two stages cover intrinsic needs, while the third phase of development involves the satisfaction of extrinsic needs, and tends to evolve naturally from sustained satisfaction of the first and second phases.

(b) Review of Council's programmes

11. In changing its programme emphasis from the transfer of technology to the application of science for technological development, the Council has critically appraised its previous activities in rural technology, geology and mineral resources, and metrology, and particularly their delivery mechanisms such as training courses and networks of scientists, so as to ensure the relevance of future programmes to developing countries' perceptions of their needs. Council's previous activities (Table 1) show a considerable concentration on technological transfer to support industrial needs. In comparison, very few activities have concerned the satisfaction of basic human needs and, with one exception, most have concerned only land-based resources, neglecting the other major environments of the universe namely water, the atmosphere and outer space. There has also been no specific consideration of security and strategic needs for development, and probably rightly so because technology transfer in this area is shrouded by secrecy. However, certain aspects of basis human needs, energy, natural resources and environmental needs and industrial needs have a strategic dimension, very vital for national development and security, and global inter-dependence. Furthermore, there has been no consideration of the aesthetic, cultural and philosophical needs for science which provide indicators of society's receptiveness to science, and its realisation of conscious and universal development.

12. Thus, in defining the Council's new programme areas of energy, mineral resources, renewable natural resources, environmental planning, industrial support and science policy and organisation, project activities need to be:

(a) revised after comprehensively examining all the critical scientific issues related to development;

(b) expanded to encompass optimum realisation of the potentials of diverse environmental resources, namely land, water, the atmosphere and outer space;

(c) sensitive to the scarcity of scientific expertise in most developing countries (implying the need for versatility in such manpower that is available); and

(d) aware of the interdependence of various resources on their exploitation, their environmental effects, their future availability, their integrated management, delivery and end-use, their optimum management in relation to needs, and on their conservation for future use and sustainable development.

13. Given the wide differential in the developmental status of member countries, Council's future programmes should perhaps consider the range of sectoral needs which arise at various stages of development, and should indicate the particular research and developmental needs of each sector. Thus,

(a) activities for the low-income developing countries could focus on basic needs, such as:

- provision of potable water
- increase in food production
- enhancement of natural resources production
- extension and improvement of health services
- increase in housing quality
- stabilisation of human population growth
- increase in employment opportunity
- increase in real income
- increase in transportation and industrial infrastructure

(b) activities for the middle-income developing countries could focus on reducing inequalities, such as:

- increase in industrialisation especially in the high technology area
- increase in natural resources production
- increase in the processing of natural products
- increase in employment opportunities and skills
- increase in real income

(c) activities for the industrialised countries could focus on national benefits, such as:

- test of technology under diverse environmental and socio-cultural conditions
- adaptation of technology for external uses
- generation of technological activities invaluable to international economies

(c) Excellence in science

14. Science is the dominant mode of contemporary culture and civilisation, and is dependent essentially on its intuitive, analytical and experimental methods through which new knowledge and concepts are generated. It is society's main source of innovation, and is thereby a potent agent of social change. Its application to social and developmental problems, however, is dependent entirely on its organisational infrastructure. Science is therefore an invaluable resource to all countries whether big or small, industrialised or developing, boreal or tropical, continental or insular and richly or poorly endowed. Since science is a living mode of contemporary culture, scientists are an invaluable human resource.

15. Science knows no limits. Its advances are unpredictable, and each discovery generates its own stream of technological innovations which may be applied to social development. However, excellence in scientific research requires the following ingredients:

(a) good scientific leadership,

(b) the performance of good science,

(c) the involvement of good scientists,

(d) the commitment of all institutions, administrative as well as financial, and

(e) the perception of a reward or benefit, even if only intellectual, from participation in the scientific enterprise.

16. The potential benefits which science and technology can deliver to society will not be realised unless there exists a supportive, as well as receptive, cultural and political climate. Thus, Council's programmes should also consider the appropriate managerial and organisational mechanisms for effectively applying science to technological development. Since the momentum of science is dependent largely on the motivation of scientists at all levels, its harness for development depends on:

(a) a better appreciation by government of science and technology in policy formulation;

(b) pathways through which science can diffuse out to all economic sectors, thereby implying cooperation between government, industry, universities, professional bodies and end-users;

(c) facilities for the adaptation and adoption of foreign technology, where locally developed technology is not available;

(d) organisations and infrastructure for making possible scientific advancement which, in addition to the obvious needs for buildings and equipment, implies the provision of adequate technical and administrative support, sound management techniques and a spectrum of associations;

(e) an atmosphere for excellent performance by professional scientists in research through the accord of professional status, support staff, research facilities, research grants, communication and training support, incentives and awards, and a stimulating psycho-social environment; and

(f) the confidence and pride to develop, maintain and retain scientific expertise in member countries, especially the developing countries, in an era when the "brain drain" of scientists is ever so pervasive.

(d) International cooperation in science

17. Science is international in character and knows no national boundaries. Consequently, it flourishes wherever and whenever given the opportunity to do so, intellectual capacity for science being uniformly distributed in all human cultures and populations. International cooperative and scientific programmes are useful both in enhancing scientific capability and catalysing scientific endeavours especially in developing countries, and in enriching the developmental experience of scientists in the industrialised countries. Otherwise, investments in science must be substantial and duplicative in order to be effective.

18. The industrialised countries are well endowed with institutions for basic and applied sciences because of a variety of factors, notably:

(a) vast national investments in science in a wide variety of disciplines, and through a wide range of mechanisms;

(b) sustained investments in science over the past 150 - 250 years; and

(c) bilateral and multilateral cooperation in science, through specific programmes, to develop or reinforce centres of scientific excellence.

International scientific cooperation has thus been useful in developing or reinforcing centres of excellence in the industrialised countries, and in the establishment of complementary centres for scientific research, technological development, and education and training.

19. In the 1960's, international scientific cooperation flourished under the auspices of international non-governmental and professional institutions, such as the International Biological Programme (IBP) of the International Council of Scientific Unions (ICSU). The commitment and involvement of practising scientists, and of public and private financial institutions, made such an international cooperation possible. The industrialised Commonwealth countries (the United Kingdom, Australia, Canada, New Zealand and India) played a dominant role in many of these programmes. In the 1970's, international scientific cooperation was undertaken largely by international intergovernmental institutions, particularly of the United Nations system, such as the Man and Biosphere (MAB) Programme of UNESCO; while private ventures and funds for international scientific cooperation diminished. International scientific cooperation through intergovernmental bodies has been more successful in countries with centralised administrations, such as those with planned economies, than in countries with decentralised administrations such as those of the Commonwealth. It has also been more successful when dealing with problems critical for economic development such as international agricultural research in food production, and international health research in disease control and prevention.

20. International scientific cooperation has encountered a variety of constraints, especially in developing countries:

(a) pressing social problems resulting in a low priority given to science;

(b) the limited scope of applied science institutions;

(c) the lack of basic science institutions;

(d) the dominant teaching role of universities;

(e) the weakness in or absence of a spectrum of scientific associations and institutions;

(f) socio-cultural and politico-economic constraints to science;

(g) differing perceptions of international cooperation among parties with unequal potentials and capabilities, beside linguistic, cultural and historic differences; and

(h) the involvement of institutions, rather than scientists, as focal points for scientific cooperation.

21. Council's past programmes have been fairly successful in promoting international cooperation among scientists and institutions in areas of technology transfer, and in involving both the industrialised and the developing countries. This experience could be enhanced in order to:

(a) foster the enhancement of scientific capability necessary for the absorption, adaptation and generation of technology, especially in developing countries;

(b) reach leading and practising scientists, especially in developing countries; and

(c) involve scientists and institutions from both the developing and the industrialised countries in a more rewarding and enriching experience through an expanded programme of scientific cooperation including emerging and new areas.

22. There appears therefore a reasonable case for an expanded programme of international scientific cooperation in the Commonwealth, based on:

(a) the Commonwealth experience in international scientific cooperation;

(b) common historical and linguistic ties;

(c) the complementary benefits of international cooperation to both industrialised and developing country scientists;

(d) the reinforcement of inter-personal and inter-institutional links within the Commonwealth;

(e) the involvement of leading and practising scientists;

(f) the support of governmental and non-governmental organisations and institutions;

(g) clear and realistic technical objectives; and

(h) the commitment of Commonwealth governments at the highest levels of mobilising resources and expertise.

(e) Issues for a cooperative scientific programme

23. The success of an international cooperative scientific programme pertaining to development and heightening the quality of life, depends as much on the scientific content, as on the socio-cultural and politico-economic context of science. Several areas of science involving technology for development lend themselves to a special Commonwealth programme, such as:

(a) Basic resources:
- Survey and conservation of genetic resources
- Tropical forest ecology
- Alternative energy sources
- Atmospheric science
- High energy sources
- Space science

(b) Strategic issues:
- Integrated management of natural resources or integrated environmental management
- Coastal zone management
- Soil erosion and conservation, especially in the tropics
- Floods and droughts
- Environmental pollution, prevention and control
- Biotechnology
- Management of the maritime zone
- Metallurgy and new materials uses

(c) Technical issues:
- Applications of remote sensing
- Natural hazard forecasting
- Genetic engineering
- Applications of micro-electronics
- Sea-bed mining
- Applications of laser technology

(d) Regulatory issues:
- Metrology and standards

Other scientific areas such as food production, rural development, health, education and industrial technology are already the basis of programmes by other specialised units within the Commonwealth Secretariat. Rural technology, geology and metrology have been the basis of Council's past programmes.

24. Selection of issues for a Commonwealth cooperative programme in science is dependent on a number of criteria:

(a) a high intrinsic scientific value, contributing significantly to some branch of knowledge;

(b) sufficient challenge for scientific research, technological development and/or training;

(c) sufficient realism for generating the necessary scientific expertise and capability, both on a long-term and short-term basis, and with respect to intermediate and high technology;

(d) a balance between relatively short-term issues requiring simple to sophisticated technology and infrastructure, and relatively long-term issues requiring only sophisticated technology and infrastructure;

(e) a balance between technical and scientific advancement;

(f) relevance to both developing and industrialised country perceptions for interdependence in science and technology and economic development; and

(g) responsiveness to the needs and perceptions of member countries.

25. The identification and selection of scientific issues for a cooperative Commonwealth programme would involve the following steps:

(a) establishing networks of active scientists as project groups, special groups or expert groups on specific topics or areas of science so that they may exchange information and identify potential projects;

(b) organising meetings of working groups or task forces of these networks so that they may identify and elaborate specific scientific issues, areas and modes for collaborative research and training;

(c) seeking the advice of and reviews by professional experts as referees and consultants, in order to refine the issues and problem areas for collaborative research and training, and evaluate priorities;

(d) seeking the endorsement of Council members interested in specific issues or topics, so that collaborative research and training programmes may be implemented with governmental support; and

(e) organising reviews and evaluation of scientific projects from time to time and the function of the network groups.

26. There has been considerable emphasis on scientific activities related both to basic human needs and industrial needs in the past 15 - 20 years, especially through the allocation of funds and human expertise, and through the establishment of governmental, non-governmental and international institutions, for applied scientific research especially in the developing countries. Much of this emphasis has concerned the terrestrial environment with lesser focus on the aquatic, atmospheric and (extra-terrestrial) outer space environments. Future programmes in science would therefore need to focus on areas which could contribute interstitially both to scientific growth and to the generation of local scientific capability relevant to development. Integrated natural or environmental resources management for example is a candidate for scientific cooperation because of:

(a) Council's previous expertise in Rural Technology which embodied natural products, energy and biomass utilisation issues in the tropics and subtropics;

(b) increasing demographic pressure on natural resources particularly on freshwater, water quality, soil fertility and genetic resource diversity in the developing countries of the tropics and subtropics;

(c) the intense severity and magnitude of environmental impacts generated by purely economic and large-scale engineering developments, particularly in the tropics and subtropics;

(d) uncertainties in the global economic condition and prevailing stresses of these on developing countries in the tropics and subtropics;

(e) the rich biological diversity of tropical and subtropical environments;

(f) the differential availability of expertise in tropical natural resources and environmental management, in both the industrialised and some of the developing countries; and

(g) the need for an integrated approach to managing tropical natural resources and the environment for sustainable development enhancing the quality of life.

Since soil fertility and water quality are critical for human development, such a scientific programme could focus on the issue of water quality and availability, or of nutrient mobility and availability.

27. Most of the advances in science have been due to extrinsic factors such as curiosity-oriented research. In comparison, most of the advances in the application of science (ie technology) are due to intrinsic factors affecting society such as basic human needs for water, food, shelter, clothing, and health. The development of applied science is therefore linked to the development of an integrally functioning national economy. Science of this nature is necessarily medium- to long-term and requires high technology, not necessarily capital intensive. Although this kind of science may be limited to the participation of the more industrialised countries, it is equally important to the developing countries if only to generate an awareness of newly emerging technologies and instil a sense of national pride in science and technology. Such scientific programmes could facilitate the training of scientists from developing countries over the medium- to long-term until a critical mass of expertise and infrastructure would be available for self-sustaining national or regional programmes. The technologies emanating from such scientific programmes would have major impacts on development in the next 10 - 20 years, if not sooner. The Commonwealth has a significant proportion of distinguished scholars and Nobel Laureates with expertise for exploring the feasibility of such special programmes which could enhance science through Commonwealth cooperation.

(f) Execution of cooperative research and training

28. Scientific research and training, under supervision and with peer review is the most reliable vehicle for implanting and generating local scientific expertise. This process depends on the following criteria for effectiveness:

(a) independence in undertaking research, coordination in approaches involving the scientists themselves, and the minimum of administrative constraints;

(b) an adequate supply of equipment and facilities, and support staff;

(c) national and international cooperation of both scientists and scientific institutions;

(d) special supplementary studies which may be commissioned, and specialised training internships or assignments;

(e) periodic review both internally and externally by independent referees, to upgrade the quality of the science and of the training undertaken;

(f) publication and dissemination of research and training results, for critical review by peers; and

(g) a system of rewards, awards and incentives that will recognise good science, and reinforce commitment to it.

This is a most difficult but challenging undertaking, one that could reinforce the functional concept of Commonwealth cooperation.

29. The development of indigenous scientific capability also depends on the identification and involvement of incipient or proven scientific leaders and scientists. This identification is dependant on the selectivity and quality of the science education and the scientific research systems. It needs to be conducted not only through Council members and governmental institutions as usual, but also through universities, private institutions and professional scientific bodies on a complementary basis, with a view to reaching a wider audience of active and committed scientists. In this context, the involvement of good scientists in Council programmes has to be voluntary and as flexible as necessary in order to:

(a) conduct research and training of good quality

(b) promote research and training in special techniques, for instance through fellowships and grants, and

(c) promote recognition for scientific discovery through a system of awards.

The attrition rate of research scientists is very high (about 60 - 80%) and increases exponentially with age, even in the best of circumstances in industrialised countries. It is accelerated by politico-economic and socio-cultural constraints to the freedom for, and challenges of, research and training in science.

TABLE 1

REVIEW OF COUNCIL'S PROJECT ACTIVITIES 1976 - 1982

(Project Numbers in brackets)

Environment / Focus	Land	Water	Atmosphere	Outer Space
(A) Basic Human Needs (Food, health, shelter, education)	2 (10, 11)	0	0	0
(b) Energy, Natural Resources & Environmental Needs	9 (1, 2, 3, 4, 5, 12, 15, 18, 19)	1 (16)	0	0
(C) Industrial Needs	7 (6, 7, 8, 9, 13, 14, 17)	0	0	0
(D) Security and Defence Needs	0	0	0	0
(E) Aesthetic, Cultural and Philosophical Needs	0	0	0	0

Key to Project Numbers

1. African Energy
2. Caribbean Energy
3. Asia-Pacific Rural Technology Water Hyacinth
4. Asia-Pacific Rural Technology Energy
5. Asia-Pacific Rural Technology Biogas Systems
6. Asia-Pacific Rural Technology Prime Movers
7. Asia-Pacific Rural Technology Agro-industries
8. Asia-Pacific Rural Technology Light Engineering
9. Asia-Pacific Rural Technology Paddy By-products
10. Asia-Pacific Rural Technology Rural Housing
11. Solar Cooling
12. Asia-Pacific Rural Technology Medicinal Plants
13. Asia-Pacific Metrology
14. Caribbean Metrology
15. Mineral Resources
16. Asia-Pacific Rural Technology Water Treatment
17. African Standardization
18. Caribbean Natural Products
19. African Natural Products

Commonwealth Science Council Programmes

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1. INTRODUCTION

1.1 The basic objective of the Commonwealth Science Council (CSC) is to increase the capabilities of individual nations to develop and to use science and technology for their economic, social and environmental development through promoting collaboration between member countries of the Commonwealth. Within the scope of this objective, the Council continues to carry on the tradition of intergovernmental liaison and cooperation which dates back to the 1930s when formal cooperation between Commonwealth government organisations engaged in scientific research was first achieved.

1.2 The need to establish a permanent scientific liaison between the Commonwealth countries led to the founding of the Council in 1946 as a Standing Committee of the British Commonwealth Scientific Officials Conference, with a Secretariat based in London. In 1958 the Standing Committee was reconstituted as the British Commonwealth Scientific Committee. To focus on its Commonwealth-wide liaison involvement, the Committee was re-named in 1964, the Commonwealth Scientific Committee. The present name, viz; the Commonwealth Science Council was adopted at a meeting of Commonwealth Heads of Government in Kingston, Jamaica, in May 1975, when a Memorandum of Understanding on the Council was endorsed.

1.3 While membership of the Council is limited to contributing governments, in the furtherance of its objectives, however, the Council addresses its activities to all Commonwealth countries, associated states, and dependent states. In its thrust of activities the Council identifies areas suitable for collaboration, which are pursued through information exchange, meetings, discussions, seminars, training workshops, study tours, training attachments, technical advice, personnel exchange, surveys, review meetings or research activities. In this way specific programmes are defined and pertinent projects are identified for collaborative research activities by scientists in countries or regions concerned.

1.4 Over the last 15 - 20 years the Council's activity initially emphasized information dissemination. In 1976, programme activities were introduced which emphasized applied science and the transfer of technology readily available but inadequately employed. This resulted in three programme areas: Rural Development, Metrology and Standardization, Mineral Resources and Geology.

1.5 The 12th Biennial Meeting of the Council in Kuala Lumpur in August 1982 approved this continued emphasis on applied science, stressing a more active promotion of science for application to technology for development, especially of disadvantaged Commonwealth countries. This emphasis on science for technology

for development implies an expanded programme of scientific cooperation and increased enhancement of scientific expertise through research, training and information dissemination.

1.6 The Council's present thrust of activities centre on six programme areas which address the development needs of member countries: Energy, Mineral Resources, Renewable Natural Resources, Environmental Planning, Industrial Support, and Science Policy and Organisation. A list of publications of the Council's activities is appended (Appendix)

2 ENERGY PROGRAMME

2.1 The Council's Energy Programme was founded to enhance local expertise in appropriate energy supplies (conventional, alternative, or renewable) and upgrade existing energy technologies (such as through transfer of viable renewable energy technology) for sustainable development. Activities in the Energy Programme has been mainly through three Regional Energy Programmes, namely the Caribbean Alternative Energy Programme (CAEP), the African Energy Programme (AEP), and the Asia-Pacific Rural Technology Programme (APRTP). The focus of the activities have been on the development of renewable energy technologies and the evaluation of rural energy needs and resources.

2.2 Through the activities of the Energy Programme:

(i) participating countries have been sensitized to the issue of Energy as a vital resource for sustainable development, whether social, economic, or industrial;

(ii) R & D projects continue to be pursued in solar crop drying, charcoal production, and biogas production, in the African region; and

(iii) substantial collection of meteorological data (wind systems, local solar isolation factors, etc) and a significant use of energy accounting (energy assessment auditing) are being carried out in the Caribben region.

2.3 The Energy Programme's thrust of future activities are envisaged:

(i) to focus on assistance to member countries to initiate, develop, and apply coherent energy policies and plans in the context of their overall socio-economic needs;

(ii) to assess the feasibility of each of a number of other projects in the African region, including solar heating and cooling, wind energy for water pumping, wind electricity, and meteorological data collection, through workshops and background studies; and

(iii) to enhance the development of networks for information gathering and dissemination within the Caribbean region.

(a) Caribbean Alternative Energy Programme (CAEP)

2.4 The Caribbean Alternative Energy Programme (CAEP) was initiated in 1977 and its major projects include:

(i) collection and analysis of weather data, coordinated by the Caribbean Meteorology Institute in Barbados, to profile wind systems, measure local insolation factors, and survey sites for mini-hydros;

(ii) energy accounting for Antigua, Barbados, Dominica, Guyana, and Montserrat;

(iii) solar crop drying and a comparative study of various types of small crop dryers;

(iv) bagasse for electricity generation, along the lines of thermo-electrical power; and

(v) miscellaneous projects on demonstration biogas plants, testing of windmills, and improvement of charcoal technology.

(b) African Energy Programme (AEP)

2.5 The African Energy Programme (AEP), initiated in 1979, has concerned rural energy supplies in view of a growing crisis in fuelwood reserves and limited potential for rural electrification schemes. The Programme emphasises three projects with Overseas Development Administration (UK) funding:

(i) solar crop drying project, to conserve and preserve food supplies through an appropriate solar energy technology;

(ii) biogas production project, to explore the potentialities of biogas for heating, cooking, lighting, and engine powering;

(iii) charcoal production and utilization project; and

(iv) miscellaneous projects concerned with solar heating and cooling, wind electricity production, meteorological data collection/analysis, and wind energy for water pumping.

(c) Asia-Pacific Rural Technology Programme (APRTP)

2.6 The energy component of APRTP comprises:

(i) study of rural energy needs and resources; and

(ii) integrated biogas systems.

3 MINERAL RESOURCES PROGRAMME

3.1 The Council's Mineral Resources Programme aims to assist development of local expertise in the mapping, exploration, extraction, analysis, management, and utilization of mineral resources. This Programme is advised by the Commonwealth Committee on Mineral Resources and Geology (CCMRG).

The new thrusts of the Mineral Resources Programme centre around:

(i) geological mapping: methods of remote sensing or photographic imagery techniques;

(ii) mineral exploration (terrestrial, marine, estuarine or offshore): geochemical and geophysical methods;

(iii) mineral resources analysis: authentication of mineral resources of economic values;

(iv) hydrological and hydrogeological survey: the assessment and the management of underground and surface water resources.

3.2 A bi-monthly Earth Sciences Newsletter is published to disseminate current information on geological and mineral resources in member countries.

4 RENEWABLE NATURAL RESOURCES PROGRAMME

4.1 The Renewable Natural Resources Programme was initiated to assist development of local expertise in the survey, identification, collection, authentication, culture, conservation and management techniques and methodologies for natural resources (viz: plant, animal and microbial genetic) with potentially viable socio-economic benefits (protein-nutritional, medicinal-pharmaceutic, or economic-commercial).

Activities in this Programme have comprised mainly training workshops, field surveys and commissioned studies, implemented under the auspices of three Regional Programmes, namely, the Caribbean Natural Products Programme (CNP), the African Natural Products Programme (ANP), and the Asia-Pacific Rural Technology Programme (APRTP).

4.2 The Council's past activities on Renewable Natural Resources have been fairly successful in assisting to initiate national programmes on evaluation of specific natural resources, especially marine algae and seaweeds in the Caribbean and Africa, and medicinal plants in the Asia-Pacific and the Caribbean; and in identifying a number of projects for collaborative inter-country or inter-regional effort.

Future activities under this Programme will strive to enhance further the development of indigenous capabilities. It is envisaged to enlarge the scope of the programme to include:

(i) conservation and management of genetic resources for sustainable human use; and

(ii) the development and preparation of new commercial products such as pharmaceuticals, using genetic engineering and fermentation technology methods.

(a) Caribbean Natural Products Programme (CNP)

4.3 The Caribbean Natural Products Programme (CNP) was founded in Trinidad and Tobago in 1979. Its scope of activity centres around three projects, namely:

(i) ethnobotany and botanical taxonomy, including ethnopharmaceutic/ethnobotanic survey of traditional medicinal plants of the region;

(ii) authentication of medicinal plants, in order to isolate those plant resources with medicinal - pharmaceutic values; and

(iii) marine resources and aquaculture, to isolate various non-food marine natural products including seaweeds, various invertebrates, and trash fish.

For each of these areas, a training workshop has been organised to introduce the techniques and methodologies for identification, survey, and classification.

(b) African Natural Products Programme (ANP)

4.4 The African Natural Products Programme (ANP) was initiated in 1981. To-date the Programme addresses itself to a number of major programme areas, including:

(i) medicinal plants;

(ii) agro-industrial wastes;

(iii) plant-derived, aquatic, forest products;

Ten projects have been identified for regional cooperation:

(i) Production of Rhizobium inoculants on agro-industrial wastes and by-products;

(ii) the utilisation of agro-industrial wastes and by-products in animal feeds;

(iii) survey of medicinal plants and their uses;

(iv) selected medicinal plants for use in health care;

(v) edible and non-edible oils from non-conventional plant sources;

(vi) gums, raisins and phenolic compounds from local plants;

(vii) survey and screening of algae of economic importance in Eastern Africa;

(viii) the potential of lake fly biomass from African lakes for human and animal use;

(ix) forest trees beneficial to agro-forestry and soil-enriching trees of economic value; and

(x) evaluation and utilization of major secondary species in tropical forests.

(c) Asia-Pacific Rural Technology Programme (APRTP)

4.5 The Asia-Pacific Rural Technology Programme (APRTP) was launched in 1978 and is diverse in scope. Two of the projects of this Programme fall under the Natural Resources Programme, namely:

(i) cultivation and processing of medicinal plants, and

(ii) management of water hyacinth.

The first project aims to explore the medicinal-pharmaceutic values of local flora for socio-economic and agro-industrial purposes. The second project has explored:

(i) the viable management of the water hyacinth through biological control using safe and environmentally acceptable agents for suppression, and

(ii) the utilisation of the water hyacinth as feedstock for biogas digesters and also as resource for paper.

5 ENVIRONMENTAL PLANNING PROGRAMME

5.1 The Environmental Planning Programme aims to assist the development of local expertise in the assessment, management, and planning of the environmental resources for sustainable ecological balance. Basically, the Programme seeks to examine the integrated use of natural resources in relation to the environment. This Programme envisages to focus on:

(i) environmental management, to help ascertain the nature and extent of resources as they occur locally in the environment in the context of the world conservation strategy;

(ii) environmental assessment, to identify, predict, interpret, and communicate information on, effects of extraneous inputs (such as a policy, a legislation, or an engineering project) into an existing ecological balance;

(iii) ecosystem evaluation, to assess the characteristics of ecosystems for purposes of matching to appropriate or suitable use, and to develop ecological indicators.

6 INDUSTRIAL SUPPORT PROGRAMME

6.1 The Council's Industrial Support Programme assists with the transfer, adoption or adaptation of technology for the industrialisation of Third World Commonwealth countries. Under the auspices of the Programme the Council has implemented three regional programmes, namely, the Asia-Pacific Metrology Programme (APMP), the African Programme on Standardization and Quality Control (APSQC), and the Caribbean Metrology Programme (CMP) to build up an infrastructure knowledgeable in aspects pertaining to scientific measurement (for exactitude and credibility), standardization (for national, regional, or inter-national recognizability), and quality control (for national, regional, or inter-national acceptability). Future activities of the Programme are envisaged to include a broadening of the present scope to include Microcomputers (CAD, microprocessor applications, etc) and New Industrial Materials (alloys, plastics, composites, ceramics, or biological materials).

(a) Asia-Pacific Metrology Programme (APMP)

6.2 The Asia-Pacific Metrology Programme (APMP) was founded in 1977 and has broadened its scope to enable participation of non-Commonwealth countries in the region. Its activities have concentrated around:

(i) measurement standards and calibration facilities, including travelling standards;

(ii) intercomparison of national standards of measurement;

(iii) harmonisation of testing and calibration procedures; and

(iv) training of laboratory staff.

The implementation of these activities are viewed as assisting improvement in the quality of manufactured goods and enhancing the removal of trade barriers.

(b) Caribbean Metrology Programme (CMP)

6.3 The Council's Caribbean Metrology Programme (CMP) was launched in 1979, and encompasses legal metrology, industrial metrology, information dissemination, and training. Under the auspices of this Programme, the following activities have been initiated:

(i) intercomparison of measurement standards;

(ii) conversion of trade equipment to SI base; and

(iii) establishment of working standards in mass, length, and volume.

Of both scientific and fiscal importance has been the adoption or adaptation to the OIML System of Alcoholometry, since CARICOM member states are exporters of rum to EEC.

(c) African Programme on Standardization and Quality Control (APSQC)

The African Programme on Standardization and Quality Control (APSQC) was launched in 1978 and its focus of activities are on:

(i) formulation of standards and metrication;

(ii) sharing of testing and calibration facilities;

(iii) information dissemination; and

(iv) training

In order to enhance collaboration with regional bodies, a Memorandum of Understanding has been signed between the Commonwealth Science Council (CSC) and the African Regional Organisation for Standardization (ARSO). Under this memorandum, ARSO will incorporate all the activities of APSQC effective January 1984.

7 SCIENCE POLICY AND ORGANISATION PROGRAMME

7.1 The Science Policy and Organisation Programme was launched in July 1983, and comprises:

(i) research management and infrastructure;

(ii) technological acculturation; and

(iii) information dissemination.

7.2 Research management and infrastructure activities was established in 1974, to improve the quality of research management in developing countries. A variety of activities have been organised on communication of research results, improvement in the effectiveness of research institutions, and on links between national scientific infrastructure and light industry. Future activities will focus on evaluative methodologies for national R & D efforts, role of indigenous professional scientific bodies, and role of research or scientific councils in policy formulation and planning.

7.3 Technological acculturation concerns the process of acquisition of technology in development concurrent with the transition from a traditional to a modern technological culture. This focus should assist the development of local expertise in technological change. It involves the identification of reliable statistical indicators of local scientific and technological innovations for measuring productivity and development. Most science and technology indicators concern themselves with input and output data such as:

(i) expenditure on scientific research, experimental development, and technological innovation on a 'per capita' basis;

(ii) manpower development in scientific research, experimental development, and technological innovation on 'per capita';

(iii) the number of scientific books published each year;

(iv) the number of scientific papers produced by practising scientists each year;

(v) the number of citations given to scientific papers producted by practising scientists each year; and

(vi) the extent to which a product of high technology has been accepted expressed as 'per capita' figures.

7.4 Information dissemination concerns methodologies for scientific and technological information acquisition and storage, generation and transfer, and propriety and patenting, especially in relation to its application to development. Activities in this area have existed in the past such as the production of the Earth Sciences Newsletter and the reports of seminars, workshops, surveys, and studies. Future activities in the area will focus on:

(i) the application of computer-based information for decision-making, and

(ii) the launching of a newsletter on advances in science and technology for development.

8 FELLOWSHIP SCHEME (CSCFS)

8.1 The Commonwealth Science Council Fellowship Scheme aims to develop local expertise through opportunities for skill enhancement and professional training for scientists involved in the Council's programmes. It was conceived in 1977 and established in 1980.

MODALITIES OF SCIENTIFIC COOPERATION IN THE COMMONWEALTH

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(A) INTRODUCTION

1. The Commonwealth Science Council's purpose is to increase the capabilities of individual member countries to generate and use science and technology for their economic, social and environmental development, through collaboration among Commonwealth nations. This purpose is achieved through 13 objectives undertaken by scientific and technical cooperation in the Commonwealth, and outlined in Council's Memorandum of Understanding with the Commonwealth Secretariat:

   .1 to foster the most effective national use of science and technology

   .2 to promote the exchange of information

   .3 to promote the exchange of personnel

   .4 to sponsor studies to assist the application of science and technology for development

   .5 to identify areas for potential collaboration in particular fields of scientific endeavour

   .6 to formulate methods for effecting close collaboration

   .7 to promote, as appropriate, action-oriented projects of suitable size and content

   .8 to share training facilities relevant to such projects

   .9 to review periodically the progress of such projects

   .10 to cooperate with other Commonwealth bodies in the pursuit of common objectives

   .11 to locate appropriate expertise and sources of funds, on the request of individual member countries, to assist them in the pursuit of solutions to their scientific and technological problems, and the development of national capability

   .12 to develop and maintain, as may be appropriate, contacts with and among professional organisations and institutions of science and technology in member countries

   .13 to offer scientific and technical advice to the Commonwealth Secretary-General.

2. Involving scientists of the highest calibre is invaluable not only for national development but, also, for achieving Commonwealth cooperation. A variety of modes are therefore necessary for enhancing scientific cooperation, and the following 12 modes of scientific cooperation originate from Council's objectives:

.1 Information exchange

.2 Fellowships

.3 Studies and surveys

.4 Collaborative research funds

.5 Expert consultancy and advice

.6 Meetings, task forces, working groups and expert panels

.7 Training courses, workshops, seminars and demonstrations

.8 Special research and training projects

.9 Project review and evaluation

.10 Collaboration with Commonwealth, international and non-governmental organisations

.11 International sectoral exchange and collaboration

.12 International intersectoral exchange and collaboration

3. The relationship between these 12 modes of scientific cooperation and Council's 13 objectives for achieving its purpose is illustrated in Table 1. Not all subject areas or projects identified as suitable for scientific cooperation are implementable through each and every modality. For each, the modality of scientific cooperation will have to be determined by scientific experts, by Council's secretariat, and by Council and its Executive Committee. The Expert Group's advice would be an invaluable guide to Council in this regard.

(B) ANALYSIS AND INTERPRETATION

(a) General

4. Council has utilised most of the 12 modes of scientific cooperation emanating from its purpose and objectives, to a greater or lesser extent, in its previous programmes. This experience is discussed below. Some modes have directly involved financial support from Council, others have not. Some modes have been utilised more intensively than others, depending on the availability of funds and the objective of the project or activity. Mode or modes of scientific cooperation in the Commonwealth may be selected on the basis of five criteria in respect of scientific and technological areas or projects amenable to cooperative effort:

.1 Technical objective: so that the mode(s) match(es) the technical objective of each scientific area or project, which must be clearly identified;

.2 Complementarity: so that the mode(s) reinforce(s) or complement(s) other avenues for enhancing the scientific enterprise, but are not mutually exclusive;

.3 Multiplier effect: so that the mode(s) generate(s) a multiplier effect in the enhancement of scientific and technological capability in the subject area or sector in the member countries;

.4 Commonwealth concerns: so that the mode(s) address(es) similar concerns on transnational environmental or resource issues, the harmonisation of techniques for a potential Commonwealth market, or the supra-national scale of human and financial resources required for the project objective, of two or more member countries; and

.5 Commonwealth interest: so that the mode(s) respond(s) to common or mutually reciprocal interest(s) for self-reliance and interdependence, of two or more member countries.

5. In addition, these 12 modalities of scientific cooperation have differing impacts on the four functional objectives of Council (Table 2):

.1 Strengthening networks for scientific and technological action;

.2 Monitoring, evaluating and advising on science and technology;

.3 Promoting scientific research and technological development; and

.4 Enhancing the diversification of science and technology for economic competitiveness.

All modes of scientific cooperation strengthen networks which are the basis for institution-building in the Commonwealth community.

6. The 1982 Review Group of the Commonwealth Secretariat considered the following 14 guidelines as a framework for testing the suitability of programmes and projects for Commonwealth action:

.1 Priorities: that they be in accordance with the priorities of Commonwealth governments, including areas of special concern identified by Heads of Government, and be expected to attract the support of governments involved;

.2 Functional competence: that they be within the special functional competence of the Commonwealth characterised by its heterogenous membership and ease of dialogue, such as its capability as an international catalyst, its performance of an international cooperative service;

.3 Commonwealth dimension: that they be clearly identifiable as a Commonwealth project involving member countries, but not necessarily excluding non-members, and capitalising on linguistic, cultural, social, economic, administrative and other links between member countries;

.4 Cooperative progress: that they offer significant scope for facilitating progress in international cooperation in areas of substantial interest to Commonwealth countries;

.5 Information exchange: that they provide essential technical and economic information to member countries of the Commonwealth;

.6 Appropriate funding: that they be undertaken only if an appropriate source of funds can be identified within or without the Commonwealth;

.7 Collaboration: that they involve collaboration and, where possible, cost-sharing with international, regional, national and non-governmental agencies already active in the field, so as to complement or supplement their efforts, but not duplicate them;

.8 Technical competence: that they be within the technical competence of the secretariat and involve the optimum use of existing staff;

.9 Scope: that they be either complete in themselves or, if catalytic, be designed for continuation by other resources when secretariat support comes to an end;

.10 Duration: that they be authorised for a determined period, sufficient for the production of beneficial results, with an extension dependent on a review, on an assessment of its responsiveness to the needs of governments, and on the expectation that governments may assume responsibility for it after an agreed period;

.11 Cost-effective: that they be cost-effective so as to produce ascertainable benefits in receiving or participating countries within a reasonable period of time;

.12 Regional dimension: that they promote regional cooperation and the involvement of regional organisations, where appropriate;

.13 Training: that they include a training component, wherever possible, in order to enhance local capability and self-reliance; and

.14 Disadvantaged countries: that they give special attention to smaller, poorer and more disadvantaged countries so that they may overcome their special problems.

The guidelines appear equally valid for Council's future programmes and projects.

(b) Information exchange

7. Information exchange is the basic mode of cooperation in the Commonwealth and may take several forms:

.1 Newsletters, Technical Memoranda, Executive Summaries, Reviews and Annual Reports: a compilation of recent findings, scientists and institutions in the subject area; discussion of issues critical to development in the subject area; as undertaken previously in Council's Asia-Pacific Rural Technology Programme, and on a continuing basis with the geological newsletter, with funds from Council's Regular Budget; promoting interaction and feedback within specific networks and programmes, and between Council members.

.2 Computerised data linkages: use of electronic mail systems, existing data banks and CODATA experiments to compile and distribute bibliographic material; not undertaken previously in Council's programmes.

.3 Publications: on methodologies, research results and syntheses; preferably jointly with other institutions, as undertaken occasionally in Council's Asia-Pacific Rural Technology programme and geological programme with funds from Council's Regular Budget; may take the form of technical reports, articles in learned journals and books.

8. Information exchange as a mode of Commonwealth cooperation should have at least the following attributes:

.1 be undertaken in any subject area of science and technology, critical to the development of member countries;

.2 involve scientists, scientific and technological laboratories, professional scientific bodies and, even, Council's secretariat, provided they or it possess technical expertise in the subject area;

.3 involve members of Council's project networks, one of whom should be the Project Coordinator;

.4 involve a grant of £500 - £1,000 per network per year from Council's Regular Budget, with funds being carried over to subsequent years and with the grant renewable up to three times, on request, in the life of the specific project.

(c) Fellowships

9. Fellowships provide opportunities for research scientists and technologists to pursue their work or to continue their training at the most prestigious laboratories and institutions in other Commonwealth countries. The fellowships scheme may support three types of fellows:

.1 Basic fellowships: awarded to young people who are pursuing research including that for their higher degree, and wish to pursue their research or learn techniques in another country; Council's previous experience with fellowships falls in this category and has been supported from the Project Fund;

.2 Advanced fellowships: awarded to scientists possessing a PhD or its equivalent, and/or sufficient research experience, so as to enable them to conduct independent research in another country; and

.3 Senior fellowships: awarded to senior scientists with high professional standing, for visits to and work in laboratories in another country.

10. The fellowship scheme as a mode of Commonwealth cooperation should have at least the following attributes:

.1 be flexible enough to offer international mobility to scientists at different stages of their careers, and thus be managed independent of national regulations;

.2 be responsive to prevailing national needs, so that each member country may direct priority support towards selected scientific areas or professions, as deemed necessary; however, fellows may generally choose not only the subject of research or study but, also, the place where they wish to pursue it, and should normally undertake to return home at the end of their fellowships, to make use of the knowledge gained from their training abroad;

.3 vary in value from country to country, depending upon the fellowship's length of tenure, but should normally cover international travel and living costs and laboratory or tuition fees, wherever applicable; however, due to rising costs and financial limitations, it may cover only part of the total expenses of fellows, thereby supplementing other national sources of funds; be supported at least partially by funds from Council's Programme Budget or Project Fund;

.4 vary in duration depending on the type of fellowship and the conditions in the host country, with 9 - 12 months being normal for some research visits and 1 - 6 months being appropriate for most research visits including those concerned with harmonisation of techniques; and

.5 be applicable to all fields of science responsive to national needs and priorities, especially interdisciplinary areas such as oceanography, ecology, biophysics, applied mathematics and systems science.

(d) Studies and surveys

11. Studies and surveys should focus on scientific and technological issues relevant to the development of a number of Commonwealth member countries. They should elucidate issues or problems in science and technology on a cooperative basis; or identify projects in science and technology for Commonwealth cooperation. They should have a specific focus and a clear outcome. They have been supported in the past by Council through Commissioned Studies in its Regular Budget and through the Project Fund; and by the Commonwealth Fund for Technical Cooperation through allocation for surveys.

12. Studies and surveys should have at least the following attributes:

.1 concern basic sciences, applied sciences, scientific services, technological development, organisation of science and technology, technological impacts, science policy, science education, scientific manpower or any such issue pertaining to development;

.2 vary in nature, complexity and duration, from time to time, depending on the needs of member countries;

.3 vary in costing depending on their nature, complexity and duration, with funds being provided by Council through Commissioned Studies under its Regular Budget and through its Programme Budget, and by the Commonwealth Fund for Technical Cooperation on a case by case basis; and

.4 may be funded on the basis of advertisement to scientists in Commonwealth countries, with the choice of a successful Project Coordinator being dependent on the comprehensiveness of his coverage, the clarity of issues and interlinkages, the novelty of his approach and the perception of his ability to undertake the study or survey.

(e) Collaborative research grants

13. Grants should be available for enhancing scientific research on a collaborative basis by pooling the capabilities and resources of different groups of scientists, on specific research projects, in two or more laboratories, in different member countries of the Commonwealth. These grants should specifically assist projects which rely mainly on national funding, and where international collaboration entails costs that are not met from other sources. The projects supported should be those carried out as a joint effort between teams in university, government and private institutions involved in scientific research, as in the Water Hyacinth Project of the Asia-Pacific Rural Technology Programme, which was funded externally by the United Nations Environment Programme (UNEP).

Council does not have an allocation of funds to support collaborative research, though collaborative research has been supported from Council's Project Fund (a contingency fund) and could be supported by voluntary contributions to the Programme Budget. Research grants are not available from the Commonwealth Fund for Technical Cooperation (CFTC). External funds for collaborative research are available on a case by case basis, but are ad-hoc and require a long gestation period. Council needs a financial capacity to prime collaborative research by modest outlays of funds.

14. Grants for collaborative research should have at least the following attributes:

.1 the research proposal should be specific, carried out jointly by research scientists in at least two member countries, include the exchange of personnel on the basis of short visits, rely on other support for its basic costs, may occasionally include the cost of equipment and materials required specifically for the project, and should build upon common research already under way in respective institutions;

.2 most fields of science should be eligible for grants, though support should not be given to project areas actively supported by other international funding agencies, and emphasis should be given to fundamental aspects of science applicable to development, rather than technological development, to the involvement of both theoreticians and experimentalists, and to research of an interdisciplinary nature;

.3 grants should normally cover international travel and subsistence expenses for investigators when working in each other's institutions abroad, with up to 20% used to cover running expenses so that there is some flexibility in carrying out the project;

.4 grants should normally average of £5,000 for an initial period of one year, with funds being carried over to a second year if necessary, with a renewal of the grant being requested and being contingent on the achievement of significant progress, with grants being renewable no more than twice with projects being supported for a maximum of four years and with funds being available through Council's Programme Budget; and

.5 the collaborative research should involve Principal Investigators in each collaborating country, each being responsible for the involvement of his research team in ther international project, and each being a senior scientists, permanently resident in a Commonwealth country, normally having at least five years research experience and being on a permanent appointment in a higher educational, governmental or industrial research laboratory; one of the Principal Investigators should be designated the Project Coordinator, who should be the contact between the Council and the collaborating teams, and be responsible to Council for reporting and accounting.

(f) Expert consultancy and advice

15. Expert consultancy is a cooperative mechanism whereby scientific experts from one country advise scientists of another country in the Commonwealth in the identification and solution of their problems in science and technology. It should have a specific focus and a clear outcome. Council has undertaken expert consultancy and advice in the past in its Asia-Pacific Metrology Programme and its African Standardisation and Quality Control Programme where experts from a more developed laboratroy in one country have helped the upgrading of facilities and personnel in a less developed laboratory in another country.

Such expert consultancy has been supported financially by institutions in an industrialised country or by the Commonwealth Fund for Technical Cooperation (CFTC). CFTC resources are limited for short-term consultancies which are the kind conducive to problem identification and solution. Funds for these could be available under Council's Programme Budget, besides institutional resources in industrialised countries.

16. Expert consultancies in scientific and technological problem identification and solution should have at least the following attributes:

.1 concern basic sciences, applied sciences, scientific research, research and development funding, scientific services, technological development, organisation of science and technology, technological impacts, science policy, science education, scientific manpower or such issue on the application of science to development;

.2 involve the provision of international travel and subsistence costs with the donor country providing the salary component and leave arrangements of a senior scientist as the consultant, and the recipient country providing local expenses and hospitality;

.3 the nature, complexity and duration of each consultancy would vary depending on the request from the member country and its problems in science and technology;

.4 expert consultation may be based on its advertisement among scientists in Commonwealth countries, and/or on a roster of experts developed by Council's secretariat; and

.5 the cost of expert consultancy should vary according to the nature, complexity, location and duration of the mission, and some funds for short-term consultants should be available through Council's Programme Budget.

(g) Meetings, task forces, working groups and expert panels

17. Meetings, task forces, working groups and expert panels should be designed to bring together scientists and engineers from various Commonwealth countries to deal with specific research problems or synthesis of research results. They should be 4 - 10 days duration, involve a limited number of participants, but not be a tutorial nature. They should assist the solution of specific research problems or the synthesis of specific research results:

.1 by an exchange of views at the frontiers of knowledge, or an exchange of experiences between scientists from different research sectors;

.2 by a critical review and assessment of the state of the art, or synthesis of research results;

.3 by the formulation of recommendations for new research directions; and/or

.4 by the formulation of plans for international scientific experiments.

Meetings of this kind have been supported in the past by Council's Regular Budget and Project Fund, by grants from the Commonwealth Fund for Technical Cooperation and by external grants. CFTC funds are no longer available for such meetings; Council thus needs to enhance its resources under the Regular Budget and the Programme Budget, while incorporating for them in external grants.

18. Meetings, task forces, working groups and expert panels should have at least the following attributes:

.1 a variety of formats and levels of organisation determined by the convenor and organiser indicating how the format/ programme would thus achieve the desired objectives.

.2 the convenor and organiser should be responsible for:

(i) preparing of the scientific programme, selecting participants conducting the workshop, and publishing the meetings report;

(ii) coordinating the assignment of tasks to each participant (invited speakers, discussants, rapporteurs, session chairman);

(iii) operating the plenary sessions (invited papers) and specialised sessions leading to the formulation of conclusions and/or recommendations;

(iv) guiding the preparation of survey papers or research results containing a critical assessment of the current state of knowledge in a given area or experiment;

(v) circulating in advance the survey papers or research results as a basis for discussions; and

(vi) forming drafting groups for the formulation of recommendations, and for editorial tasks.

.3 the expectation that each participant plays an active role, and contributes to the discussions and the preparation of reports, as appropriate;

.4 their advertisement in scientific and technical journals, where appropriate, with the invitation of participants being at the discretion of the convenor and organiser, on the basis of their contribution to research and on their potential for ensuring a successful outcome;

.5 the upper limit of participants in each event being 30 - 50 persons, with a balanced distribution of nationalities and interests from Commonwealth countries, so that the convenor and organiser may introduce into the programme, where appropriate, a variety of complementary yet diverse viewpoints;

.6 their funding being determined on a case-by-case basis, taking into account the commitment of the contributors, the size and duration of the meeting, and the work involved in preparing the final report for publication; with the convenor and organiser attempting to minimise costs by efficient organisation, choice of location (preferably in the convenor's institution or in a selected Commonwealth location), and even by joint sponsorship and support;

.7 funds being available to cover direct organisational expenses, and some international travel and living expenses of participants, with an average award for a meeting being about £10,000 for 5-days with 30 participants, and with funds being available under Council's Regular and Programme Budget;

.8 the report of meetings setting out the presentations, the conclusions of the discussions and the resultant recommendations, being published in various forms depending on the objectives and the outcome of the meeting, and being made available to a wider community of scientists and, if appropriate, policy-makers.

(h) Training courses, workshops, seminars and demonstrations

19. Training courses, workshops, seminars and demonstrations should be designed to disseminate knowledge, often not available in standard university courses, and to the formulation of contacts among scientists from different Commonwealth countries. These training activities should be at any of three levels:

.1 Advanced: for senior scientists,

.2 Basic: for junior scientists, and

.3 Technical: for technicians

They should present a carefully defined subject area in a systematic and coherently structured programme, with the subject treated in considerable depth by lecturers eminent in their field, and usually of international standing. These presentations should be made to other scientists already specialised in the field, to scientists possessing an advanced general scientific background, or to technicians.

The Council has had previous experience in organising basis and technician level training activities, especially in its special research programmes. It has had no experience in advanced level activities which would be invaluable in areas of science critical to the developing countries, especially located in the arid and tropical zones. These training activities have been funded by the Commonwealth Fund for Technical Cooperation, and would continue to be so.

20. Training courses, workshops, seminars and demonstrations should have at least the following attributes:

.1 their lecturer to student ratio being usually be 1:7, so as to enable each lecturer to allot sufficient time to develop a coherent section of the programme;

.2 the development of an adequate programme through the course being of sufficient duration, preferably 2 - 3 weeks and a minimum of 5 working days;

.3 their main lectures providing the basis for seminar discussions and the examination of recent research findings with the presentation of the latest research results by participants not dominating these training activities;

.4 their format including experimental classes besides the usual arrangement of lectures, discussions and poster sessions;

.5 most fields of natural and behavioural sciences being eligible for support with preference given to proposals in which new advances, not taught elsewhere in both industrialised and developing countries, are reported in a coherent context and with a clear tutorial intent; and with subject areas supported considerably by other sources (such as space science, nuclear energy, clinical medicine) being given low priority;

.6 their organisation as interdisciplinary meetings, with specialists in one field teaching scientists highly qualified in a different area and with the roles of lecturer and student interchanging during such an activity, as the theme of common interest is developed from the viewpoint of different sciences;

.7 their involvement of a relatively small number of participants, 25 - 35 persons at the most, so as to facilitate formal and informal discussions on the various aspects of the presentations, and their being of a quality to benefit from, and to contribute to, free exchanges at a high level;

.8 their participants being appropriate for the level of training, without necessarily excluding scientists of higher qualifications and achievement in the subject area or related fields but with the choice of participants being the responsibility of the organiser of the training activity;

.9 their financial support covering the major part of international travel and subsistence expenses of lecturers, and contributing to similar expenses of young scientists from Commonwealth countries unable to find sufficient support from other sources; these grants also being used to cover in full or in part general expenses in the organisation of the training activity, such as administration and hire of equipment; however, they often representing only part sponsorship of the activities with additional funds being obtainable from other sources including, for example, local support for certain administrative or organisational expense, or block grants from other organisations; and

.10 the lectures and relevant discussions at the training activity being published shortly after the activity with the director and organiser of the activity acting as editor and coordinating the work of the contributors.

(i) Special research and training projects

21. Special research and training projects should concentrate financial support for a limited period of time, on emerging scientific areas or those undergoing rapid change, thereby complementing other multi-disciplinary activities, with the scientific areas for special attention being identified by working groups of eminent scientists. Once a specific scientific research and training project has been identified, a project group should be formed on a network basis, comprising specialists in the discipline in member countries of the Commonwealth, and be given maximum liberty for implementing activities in their domain.

In the past, Council has been successful in combining external funds for research, such as from the United Nations Environment Programme and the Overseas Development Administration, UK, with funds for training from the Commonwealth Fund for Technical Cooperation, as in the case of its Water Hyacinth Project in the Asia-Pacific Rural Technical Programme and its African Energy Programme. While external funds are available on a case by case basis for special projects, the lead time is unpredictable. Council thus needs to have access to some priming funds in its Programme Budget.

22. Special research and training projects should have at least the following attributes:

.1 the initiation and promotion of innovative activities encouraging and supporting the rapid development of inter-disciplinary scientific areas within the project groups purview, so as to attract the attention of the scientific community through original and productive paths of research and training, and to employ various mechanisms to attain these objectives including workshops, courses, fellowships and research grants;

.2 have an active life of five years, and a further year for the project group to review the work accomplished and makes recommendations for future directions in the field;

.3 activities under special projects being initiated by the project group, with a senior group member acting as Project Coordinator;

.4 unsolicited proposals being not usually entertained, but being forwarded to the relevant project group for consideration; and

.5 the value of a grant varying according to the nature and complexity of the project, and being dependent on Council's ability to solicit external funds, in part or in whole, and provide some priming from its Programme Budget to cover capital equipment, consumable materials and supplies, local travel and subsistence, support staff and technicians, international travel and subsistence, workshops, courses and fellowships.

(j) Project review and evaluation

23. Project review and evaluation may be undertaken through several forms of Commonwealth cooperation:

.1 Review meetings and workshops: of variable duration depending on the nature of the project; as undertaken in the past in the Asia-Pacific Rural Technology programme and the Asia-Pacific Metrology programme; previously supported by funds from the Commonwealth Fund for Technical Cooperation, but now no longer available; could be supported from Council's Regular and Programme Budget in the future providing a useful step in the review and evaluation process;

.2 Expert review and evaluation: based on one or more external consultants, depending on the nature and complexity of the project; providing another useful and independent step in the review and evaluation process; as undertaken in the Asia-Pacific Rural Technology Programme; previously supported from Council's Project Fund, and could be supported from Council's Regular and Programme Budget.

.3 Secretariat review and evaluation: internal review and evaluation of projects by Council's secretariat has not been undertaken critically before; and essential step for the secretariat if it is to develop its planning capability.

24. The attributes of project review and evaluation should generally conform to those of expert consultancies and working groups, and it is important that a year after the project completion be allocated to review and evaluation in the case of major projects.

(k) Collaboration with Commonwealth, international and non-governmental organisations

25. Collaboration with Commonwealth, international and non-governmental organisations in research, training and information dissemination activities should enhance:

.1 the sharing of experiences and information of mutual interest;

.2 the integrated planning, organisation and implementation of these activities on a joint basis;

.3 the economy of human and financial resources in undertaking these activities;

.4 the focus of programme activities;

.5 the identification and involvement of practising scientists in various programme activities with the view to achieving an excellent output;

.6 Council's credibility in managing international scientific and technological programmes; and

.7 Council's international visibility.

26. Commonwealth and international organisations have collaborated in Council's past programmes in the planning, organisation and implementation of research, training and information dissemination activities, thus avoiding wasteful duplication of effort (Table 3). Council has collaborated with 20 different Commonwealth and international organisations in five programme areas, with cooperation ranging from personal contacts and attendance at meetings to joint activities in training, research and information dissemination. However, the main thrust of collaboration has been in training, 19 workshops in five programme areas (1981 - 83): Energy (5), Industrial Support (4), Renewable Natural Resources (7), Mineral Resources (1), and Rural Technology (2). Collaboration has usually taken the form of assistance in the organisation of workshops, in funding especially of non-Commonwealth participants, and in the attendance of representatives (Table 4). There has not been much collaboration in research activities, with the exception of the United Nations Environment Programme (UNEP) in the water hyacinth project in Asia-Pacific region, because of previous programme emphasis on technology transfer. Council has collaborated with five international organisations in the publication of workshop proceedings, guide books and audio-visual aids. Funds for promoting collaboration are available in Council's Regular Budget.

27. The potential for collaboration with Commonwealth, international and non-governmental organisations is vast because of their large number and diversity of functions. It is necessary that Council should first identify those organisations with similar interests and activities before exploring specific areas and forms of cooperation. Council has not collaborated previously with non-governmental organisations. Establishing a dialogue with them is essential for reaching practising scientists and for achieving excellent output in scientific research, training and information dissemination, especially since there is no charge for the efforts of committed scientists towards the promotion of science. Council's initiative to establish some dialogue with them is therefore useful.

(1) International sectoral exchange and collaboration

28. International sectoral exchange and collaboration is a useful mode of scientific cooperation between institutions or research groups in industrialised and developing countries. This exchange and collaboration shall endeavour to enhance the scientific and technological research capacity of the academic, government or industrial sector in the developing country by:

.1 enhancing their opportunities for collaborative research and training,

.2 creating channels for the communication of research ideas and results, and

.3 enhancing their scientific and technological infrastructure through planning and the conduct of specific R & D projects.

Council has had some experience in international sectoral exchange and collaboration, as in the Asia-Pacific Metrology programme, the Asia-Pacific Rural Technology programme and the African Programme on Standardisation and Quality Control. These experiences were funded by the aid agencies of the industrialised countries that took lead responsibility in these programmes, such as New Zealand and Australia, by the Commonwealth Fund for Technical Cooperation or by Council's Project Fund and Fellowships Scheme. Because of the CFTC's difficulties with short-term consultancies and fellowships, and the unpredictability of aid agencies, Council needs to have access to some financial resources for such exchanges and collaboration in its Programme Budget. The secretariat expenses for such exchanges and collaboration has been met from Council's Regular Budget, and would continue to be so.

29. Projects for international sectoral exchange and collaboration should possess at least the following attributes:

.1 be chosen by national authorities and be within their priorities for economic development;

.2 involve participation in the planning and conduct of the projects on a joint venture basis, with a steering group comprising senior science administrators from participating countries being established to review the planning, implementation and funding of projects, and to advise Council regularly on the course of these projects;

.3 be appropriately funded for a limited period in the form of direct research costs, including salaries in both the developing and industrialised countries, costs of staff exchange (international travel and subsistence) between participating groups and institutions, training costs related to the research plan, and equipment and material costs required specifically for the project;

.4 involve significant additional financial contributions by participating institutions or countries from their own resources, since they provide scientific and technical personnel, pay their salary, domestic travel and other expenses, provide most of the equipment and supplied purchaseable locally, and make available necessary facilities and laboratories;

.5 embrace various scientific and technical fields such as integrated river basin management, alternative sources of energy, experimental hydrodynamics, special university course, coastal aquaculture, water resources analysis, waste-water reclamation, and upgrading scientific services (eg communications technology); and

.6 comply with the following criteria for funding purposes: (i) developing country interest, (ii) scientific merit, (iii) international institutional linkages, and (iv) significance to development; with priming funds being available through Council's Programme Budget, and with substantive funds being available from external sources.

(m) International intersectoral exchange and collaboration

30. International intersectoral exchange and collaboration is a useful mode to promote interaction between researchers from at least two countries and two research sectors (academic, government and industry). Although academic, government and industrial research sectors have different roles, their activities should be complementary; hence the need for constant interchange between these research sectors so that researchers from different sectors may work together as part of an integrated scientific and technological system, supporting national technical and social objectives. Council has had no experience in this form of exchange and collaboration, but it is one with the greatest multiplier effect for interdisciplinary advances. The mechanisms for this exchange and collaboration, appropriately adapted to new tasks and objectives should be as follows:

.1 Research fellowships for experienced scientists, mathematicians and engineers (aged 30 - 45 years) to work overseas in another Commonwealth country, for a period of 3 - 12 months, in a laboratory of a different research sector from their own, and undertaking research at any stage in the spectrum from basic research to technological development;

.2 Collaborative research grant for the collaborative research project with a definite industrial interest, with industry providing the financial support necessary for their own scientists to pursue international collaboration;

.3 Advanced training courses involving teachers and students from different research sectors and different countries, with the subject and programme of interest to more than one sector; and

.4 Advanced research workshops involving scientists from different research sectors and different countries, with the subject and programme of interest to more than one sector.

31. This exchange and collaboration should have at least the following attributes:

.1 priming funds for international travel and subsistence and certain relocation expenses incurred when living abroad, from Council's Programme Budget;

.2 facilitate the efforts of the recipient to secure any necessary additional support from other sources, by Council's acknowledgement of its scientific value; and

.3 waive any claim Council may have to an interest in the research results obtained, provide satisfactory terms are agreed between the concerned parties.

(C) FUTURE PROSPECTS

32. All the 12 modes of Commonwealth cooperation discussed above strengthen networks for scientific and technological action, and promote scientific research and technological development. However, the following salient features emerge from the foregoing discussion:

.1 that information exchange, studies and surveys and project reviews and evaluation can be undertaken through allocations in Council's Regular Budget;

.2 that fellowships, expert consultancies and international exchanges and collaboration which facilitate international mobility of scientists, are essential for the enhancement of indigenous capability. Council has limited funds, and would need to strengthen its Programme Budget for increasing available funds. International intersectoral exchanges and collaboration would have the greatest multiplier effect in terms of advancing science and technology and enhancing capability;

.3 that training activities can be undertaken on a continuing basis with funds from the Commonwealth Fund for Technical Cooperation, but some of it should be pitched at the advanced level;

.4 that research collaboration, special projects and research meetings are essential for enhancing science and scientific capability. Some priming funds would need to be available in Council's Programme Budget; and

.5 that collaboration with organisations should be pursued, especially with non-governmental organisations, with funds available through Council's Regular Budget.

Table 1 : Relationship of Modalities of Scientific Cooperation to CSC Objectives for Achieving its Purpose

CSC OBJECTIVES \ MODALITIES	1. Information exchange	2. Fellowships	3. Studies and surveys	4. Collaborative research funds	5. Expert consultancy and advice	6. Meetings, task forces, working groups and expert panels	7. Training courses, workshops, seminars and demonstrations	8. Special research and training projects	9. Project review and evaluation	10. Collaboration with international & non-governmental organisations	11. Sectoral exchange & collaboration	12. Intersectoral exchange & collaboration
1. Foster most effective national use of S & T	+	+	+	+	+	+	+	+	+	+	+	+
2. Promote exchange of information	+					+						
3. Promote exchange of personnel		+										
4. Sponsor studies on applying S & T to development			+		+							
5. Identify areas for potential S & T colloboration			+		+							
6. Formulate methods for effecting close collaboration			+		+							
7. Promote action-oriented R & D projects			+	+		+		+			+	+
8. Share training facilities						+	+	+			+	+
9. Review progress of projects					+				+			
10. Cooperate with Commonwealth bodies										+		
11. Locate appropriate expertise & sources of funds	+				+							
12. Contact professional S & T organisations & institutions										+		
13. Offer S & T advice	+				+							

Table 2 : Relationship of Modalities of Scientific Cooperation to CSC Functional Objectives

MODALITIES OF SCIENTIFIC COOPERATION	CSC FUNCTIONAL OBJECTIVES				
	1. Strengthen networks for S & T action	2. Monitor, evaluate and advise on S & T	3. Promote scientific research and technological development	4. Enhance the diversification of S & T
1. Information exchange	+	+	+	+
2. Fellowships	+		+	+
3. Studies and surveys	+	+	+	+
4. Collaborative research funds	+		+	+
5. Expert consultancy and advice	+	+		+
6. Meetings, task forces, working groups and expert panels	+	+	+	+
7. Training courses, workshops, seminars and demonstrations	+		+	+
8. Special research and training projects	+		+	
9. Project review and evaluation	+	+	+	
10. Collaboration with international and non-governmental organisations	+	+	+	
11. Sectoral exchange and collaboration	+		+	
12. Intersectoral exchange and collaboration	+		+	+

TABLE 3 : COLLABORATION BETWEEN THE COMMONWEALTH SCIENCE COUNCIL AND COMMONWEALTH AND INTERNATIONAL ORGANISATIONS (1981 - 83)

CSC PROGRAMME	ACTIVITY	COUNTRY/ REGION	DATE	INTERNATIONAL ORGANISATION NAME	NATURE OF COLLABORATION
Energy	African Biogas Symposium	Arusha Tanzania	Feb 1982	UNESCO	Organised Symposium Funded 2 participants from Africa Biogas Project funds
	Training Workshop on Wood Energy	Nairobi Kenya	Oct 1982	IDRC	Sponsored total workshop
	Workshop on Solar Crop Drying	Nairobi Kenya	Oct 1982	IDRC	£8,544.76
	Training Workshop on application of Solar Energy to Tropical Architecture	Barbados	May 1983	UNCHS	(£6,489) US$10,000 for research persons and non-Commonwealth participants also to co-produce a guide book on tropical architecture
	Training Workshop on Meteorological Data for Solar and Wind Energy programme applications	Seychelles	June 1983	ICF WMO ICF	(£906) Sponsored 1 resource person Sponsored 6 participants Sponsored 1 resource person (£1542)
INDUSTRIAL SUPPORT	Asia/Pacific Metrology Programme (second time and Frequency Intercomparison)	Asia/Pacific	1981-83	UNESCO CF	US$2,000 (£1,640) £600 for airfares for project
	Standardisation and Metrology Programme	Caribbean	1981	OIML) ISO)	Assisted in Project definition; provided Publications
	Training Workshop on Standardisation Quality Control and Metrology	Freetown Sierra Leone	Feb 1982	UNIDO) ARSO) UNESCO)	£15,000 for attendance of representatives and participants
	Workshop on Metrology in Quality Assurance	Kuala Lumpur Malaysia	April 1982	UNESCO	Supported participants from non-Commonwealth countries

CSC PROGRAMME	ACTIVITY	COUNTRY	DATE	INTERNATIONAL ORGANISATION NAME	NATURE OF COLLABORATION
INDUSTRIAL SUPPORT (Cont'd)	Regional Workshop on Metrology for Developing Countries	Sydney Australia	August/September 1982	ADAB UNESCO ASCA	Supported participants from non-Commonwealth countries published workshop proceedings
	Workshop on Bulk Measurement	Jamaica	April 1983	UNESCO	US$2000
	Asia-Pacific Metrology Programme Steering Committee Meeting	Beijing, China	September 1983	CF	Sponsored 2½ participants(£3138)
MINERAL RESOURCES	Workshop on Geological Mapping & Natural Resources Assessment & Development	Georgetown Guyana	May 1983	CF COSTED	£1316 for 2 resource persons assisted with programme planning
RENEWABLE NATURAL RESOURCES	Management of Water Hyacinth Project	Australia Sri Lanka Malaysia Fiji, India	1979-83	UNEP	US$261,611 for Project Implementation, organisation of an International Conference and attendance of Commonwealth participants, production of a film on the Water Hyacinth
	Project Group Meeting of African Natural Products Programme	Mauritius	Nov/Dec 1981	CF	Sponsored 2 participants(£1480)
	ICSU Regional Training Workshop on Equipment Training	Nairobi Kenya	April 1982	CF	Sponsored 1 participant(£600)
	Regional Workshop on Biological Control of Water Hyacinth	Bangalore India	May 1982	USDA) CIBC) CAB) CF UNEP) USDA)	Assisted in organisation. Provided resource persons Co-funded Sponsored 5 resource persons (£3700) Representative attended
	International Conference on Water Hyacinth	Hyderabad India	Feb 1983	UNEP COSTED	Co-funded Sponsored participants

CSC PROGRAMME	ACTIVITY	COUNTRY	DATE	INTERNATIONAL ORGANISATION NAME	NATURE OF COLLABORATION
RENEWABLE NATURAL RESOURCES (Cont'd)	Training Course on the application of Rhizobium Technology in Commercial Legume Growing	Nairobi Kenya	June 1982	UNEP) UNESCO ; ICRO)	Co-Sponsored
				FAO)	Representative attended
				USAID	Representative attended
	Training Workshop on the Authentication of Medicinal Plants	Guyana	January 1983	UNESCO	US$5000 for participants attendance
	Training Workshop on Marine Algal Resources Methodologies	Mombasa	May 1983		
	Training Workshop on Agro-Forestry,	Lilongwe Malawi	June 1983	CF	Sponsored 1 resource person (£1638)
	Training Workshop on Standardisation and Quality Control of Medicinal Plants	Lucknow India	Dec 1983/ Jan 1984	ESCAP/ RCTT	Representative will attend
				CF	Sponsorship of 1 resource person (£1460)
RURAL TECHNOLOGY	Workshop on Rural Housing and Environment	Dhaka Bangladesh	March 1981	UNCHS	Representative attended US$3000 for Publication of Proceedings
	Workshop on Rural Drinking Water	Madras India	May 1982	WHO	Representative attended
	Follow-up Meeting to Workshop on Rural Housing and Environment	Roorkee India	Feb 1983	UNCHS COSTED	US$10,000 (£6577) Sponsored participants
	Working on organising the Light Engineering Industry for Agriculture	Bangalore India	1981	ESCAP/ RCTT	Host
	Rural Technology Programme Fifth Steering Committee Meeting	Bangalore India	May 1982	ESCAP/ RCTT	Host

KEY TO ABBREVIATIONS

ADAB	-	Australian Development Assistance Bureau
ARSO	-	African Regional Standards Organisation
ASCA	-	Association for Science Cooperation in Asia
CAB	-	Commonwealth Agricultural Bureaux
CF	-	Commonwealth Foundation
CIBC	-	Commonwealth Institute of Biological Control
COSTED	-	Committee on Science and Technology in Developing Countries
CSIRO	-	Commonwealth Scientific and Industrial Research Organisation
ESCAP	-	Economic & Social Commission for Asia and the Pacific
FAO	-	Food and Agriculture Organisation
ICRO	-	International Cell Research Organisation
IDRC	-	International Development Research Centre
ISO	-	International Standards Organisation
OIML	-	International Organisation of Legal Metrology
RCTT	-	Regional Centre for Technological Transfer of ESCAP
UNCHS	-	United Nations Centre for Human Settlements
UNEP	-	United Nations Environmental Programme
UNESCO	-	United Nations Educational, Scientific and Cultural Organisation
UNIDO	-	United Nations Industrial Development Organisation
USAID	-	United States Agency for International Development
USDA	-	United States Department for Agriculture
WMO	-	World Meteorology Organisation

SUMMARY OF SCIENTIFIC ACTIVITIES UNDERTAKEN BY COUNCIL IN COLLABORATION WITH OTHERINTERNATIONAL ORGANISATIONS, 1981-83

ACTIVITY	PROGRAMME AREA	INTERNATIONAL ORGANISATION
TRAINING		
- assisted in organisation of workshop	Renewable Natural Resources	CIBC, ICRO, UNEP, UNESCO, USAID*, CF[xx], CAB[xx]
- hosted workshop	Rural Technology	ESCAP/RCTT*
- funded workshop (wholly)	Energy	IDRC†, UNESCO
(partly)	Energy	IDRC
	Renewable Natural Resources	UNEP, UNESCO, USAID*, ICRO
	Rural Technology	UNCHS
- funded participants	Energy	UNCHS, WMO, CF[xx]
	Industrial Support	ADAB†, ARSO*, ASCA*, UNESCO, UNIDO, CF[xx]
	Renewable Natural Resources	CIBC, UNEP, UNESCO, USAID, CF,[xx] CAB[xx]
	Mineral Resources	CF[xx]
- funded representative	Industrial Support	ARSO*, UNIDO, UNESCO
	Renewable Natural Resources	UNCHS, FAO, RCTT*, USAID*, USDA
	Rural Technology	WHO
RESEARCH	Renewable Natural Resources	UNEP
INFORMATION		
- workshop proceedings	Industrial Support	ADAB†, UNESCO, ASCA*
	Renewable Natural Resources	UNCHS
- guide book	Energy	UNCHS
- publications for Commonwealth LDCs	Industrial Support	OIML, ISO
- film	Renewable Natural Resources	UNEP
FUNDS FOR GENERAL PROGRAMME ACTIVITIES	Industrial Support	UNESCO, CF[xx]

xx Commonwealth international organisation

† Internationally-oriented national organisation based in a particular country

* Regional organisation

INSTITUTION-BUILDING THROUGH SCIENTIFIC COOPERATION IN THE COMMONWEALTH

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(A) INTRODUCTION

1. The Commonwealth Science Council's objective of strengthening the scientific and technological capability of member countries for development, has been undertaken through Commonwealth programmes of scientific cooperation. These programmes have been implemented through various mechanisms of institution-building such as networks of scientists cooperating in specific projects of Council's programmes, and networks of collaborating institutions. These institutional mechanisms have been supported by member countries and their participating institutions, with the Council member taking overall responsibility for implementing the national elements of a project, including project management and evaluation.

2. From a socio-biological perspective, a variety and a spectrum of associations are needed for organising scientists and building institutions for technological development. These associations need to be sectoral and intersectoral, and disciplinary and interdisciplinary. The organisation of these institutions for science and technology is dependent on four factors:

   (a) size and density of professional scientists for assessing the viability of their organisation physically in different ways and for different purposes;

   (b) cohesion or psycho-social bonding of specialist and generalist scientists, their hierarchical organisation and division of labour in relation to privileges, functional competence, communication and ritualised behaviour, their education and training, and their functional role in the exploration, advancement, applications, production, management, coordination and nurturing of science;

   (c) syntality or functional integration of professional scientists in response to developmental problems and challenges, based on their leadership, training, social awareness, dialogue, status and recognition; and

   (d) permeability of specialist and generalist scientists across disciplines and sectors in order to cross fertilise knowledge in interdisciplinary and intersectoral areas, and ensure their evolutionary and adaptive value in relation to the challenges of development.

(B) ANALYSIS AND INTERPRETATION

3. This paper examines Council's experience and prospects of institution-building through scientific cooperation in the Commonwealth in the future in terms of (a) project networks of scientists, (b) government institutions, (c) universities, (d) industrial, private and non-governmental institutions (e) international institutions, and (f) international centres.

(a) Project Networks

4. Project networks in Council's programmes have concerned expert scientists active on sectoral or intersectoral and disciplinary or interdisciplinary issues, from both the industrialised and developing countries; and have served three principal functions:

   a) linking national research and training efforts on a regional basis through cooperative activities around common scientific problems related to development;

   b) promoting an interchange of ideas, and comparison of results and information, through the development and application of common techniques and methodologies; and

   c) enhancing professional skills through supervised research training and/or exchange visits to research establishments within network countries

5. The research and training activities of project networks in Council's programmes have been reviewed and defined through periodic network meetings organised by Council's secretariat. These meetings fulfilled three major functions:

   a) identification of common areas for collaborative scientific research and training;

   b) providing opportunities for training in the latest techniques and methods; and

   c) providing a forum for information exchange and evaluating individual and national progress on projects through peer assessment.

6. Each project network has comprised a Principal Investigator or Project Coordinator who provides the scientific leadership and coordination of national inputs into programme activities, and national coordinators responsible for supervising and providing the scientific direction to individual participating scientists in the country. In addition, Council members in the network countries have been responsible for:

   a) identifying scientists and institutions for participation in network activities;

   b) nominating national coordinators and individual members of the project team; and

   c) securing local financial and logistic support for national components of network activities, including governmental approval for participation in the network.

   There is scope for exploring the role of professional scientific bodies and private industrial institutions in these functions.

7. The normal duration of project networks has been 3 - 5 years, with an occasional extension of up to two years. At the termination of projects, Council's secretariat seeks:

   a) to devolve the responsibility for developing future network activities to appropriate regional institutions, especially where the project has involved a substantial non-Commonwealth participation or are no longer relevant to perceived needs;

   b) to continue certain worthwhile project activities under new programmes or foci; or

   c) to cease support for project activities that have achieved their target, have been unsuccessful or are no longer relevant to perceived needs.

8. Project networks in specific subject areas will continue to be the basis for scientific cooperation in research, training and information dissemination, in Council's future programmes. Scientists and institutions involved in these networks will continue to be identified through Council members in participating countries, with the informal advice of external referees in order to ensure a high level of commitment and potential capability of participants, especially because of the shift in programme emphasis from technology transfer to science applicable to technology. Project networks will continue to function as before but with respect to the new emphasis on the application of science to technology. There is considerable scope for examining the role of professional scientific bodies in network formulation and dynamics.

(b) Governmental Institutions

9. Government institutions collaborating in Council's past programme and project networks have exceeded 170 organisations in number excluding universities (Table 1; Appendix A). These institutions have mainly consisted of government departments (51%) and national research and technical establishments (32%). Less than 50% of the national research and technical institutions have had research facilities. Nevertheless, government departments or research institutions have normally coordinated Council's projects. In some cases, especially where small island states abound, regional institutions have coordinated networks such as the Caribbean Common Market (CARICOM) has coordinated the Caribbean Metrology Programme. Organisations such as the Organisation of Eastern Caribbean States (OECS) have represented a number of small island states in Council's projects. In comparison to governmental institutions, universities and non-governmental organisations have not been actively involved in Council's programmes, probably because of the intergovernmental nature of Council and its programme emphasis on technology transfer.

10. Council members have played an active role in the identification of institutions and individual scientists participating in Council's Programmes and projects. As a consequence, most participants have tended to join Council's projects in their institutional rather than personal capacities. They have therefore been able to bring to Council's projects a variety of resources, both human and financial, available at their institutions, especially if government departments. However, as a consequence, Council's projects have not reached several good and active scientists, especially in developing countries and already

engaged in the specific subject area of a project network. While this may have been satisfactory for Council's programmes emphasising technology transfer, they may not be for new programmes emphasising the application of science to technology. It may be necessary, therefore, for Council members to look beyond the framework of government departments and scientific establishments, to universities and non-governmental organisations where they exist, in order to solicit the participation of active scientists in Council's programmes and bearing in mind the importance of allocating national resources for projects undertaken.

(c) Universities

11. Universities are vital in all countries for scientific research and training. Out of more than 300 universities in the Commonwealth, however, only 21 from 16 countries have collaborated in three programme areas: Rural Technology (7), Energy (11), and Renewable Natural Resources (3) (Table 2). One university has acted as the national coordinator of all Council's activities in that country. Nevertheless, university academics and researchers have significantly assisted in both programme and project development and participation in Council's cooperative scientific activities. For example, academics from the University of the West Indies, Imperial College and Reading University participated in the planning of the Caribbean Alternative Energy Programme; from Bangladesh University of Engineering and Technology and Reading University in planning the Asia-Pacific Rural Technology Programme; from the University of Nairobi in planning the African Energy Programme; and from the University of Mauritius in the African Natural Products Programme. Besides participation in one or more specific project activities, several universities provided regional programme and project coordination. For example, Bangladesh University of Engineering and Technology coordinated the Rural Technology Programme during 1978 - 79, the University of Zambia, the Charcoal Production and Utilisation Project since 1979, and Makerere University the Biogas Project since 1982. Dhaka University coordinated the Water Hyacinth Project nationally. Universities have provided the main collaboration in scientific research in Council's activities, particularly in Africa and the Caribbean region. Although the total number of universities associated with Council's activities is small, their contribution has been significantly large especially in cooperative research.

12. University academics in developing countries unlike scientists in non-university institutions, have to teach and conduct research despite harsh socio-economic conditions, and must make considerable efforts, in order to safeguard the international calibre and currency of their academic expertise. However, they lack the support staff, facilities and funds available in non-university scientific institutions. University staff thus require support in the form of research assistants, and funds to facilitate their active participation especially in research and training. This has been possible only where external funds have been available. In such cases, research projects in universities need a 2 - 3 year duration to facilitate the concurrent and appropriate postgraduate training for the research assistant participating in Council's activities. In one case, it was difficult to retain postgraduate fellows in one of Council's projects because of its temporary nature, resulting in frequent changes of personnel, which adversely affected the continuity of the project. Nevertheless, universities provide the multiplier effect required for enhancing indigenous scientific capabilities through Council's programmes, unlike most other institutions in a country, which is the aim of Council's programmes.

13. Universities are better suited than non-university scientific institutions, in terms of scientists generally, for pursuing collaborative research, training and information dissemination, because of the high general calibre and selection of university staff, and the multiplier effect of training staff and post-graduate and undergraduate students through programme activities, thereby enhancing indigenous scientific capabilities. More university academics and universities in the Commonwealth therefore need to be attracted into Council's programme activities, for which a register of scientists and technologists will have to be developed, so that the new programmes emphasising science may achieve their goals more successfully. Such collaboration needs to be selective, and based on the strengths of laboratories in specific project areas. Because of their infrastructural disadvantage, any such collaboration in Council's programmes will require the necessary allocations for infrastructural support to make scientific cooperation in research, training and information dissemination effective.

(d) Industrial, private and non-governmental institutions

14. Council has had very little collaboration previously with industrial, private and non-governmental institutions. Establishing a dialogue with them is essential for reaching practising scientists in different subject areas, for achieving excellent output in scientific research, training and information dissemination, and for applying science to major developmental issues, especially since there is usually no charge for the efforts of committed scientists. Council's initiative to establish some dialogue with professional scientific bodies is therefore useful; and Council members could probably collaborate with such institutions more effectively.

(e) International institutions

15. Very few international institutions such as the Commonwealth Institute for Biological Control (CIBC), have participated in Council's past programmes. Most have assisted with the planning, organisation and implementation of training and information activities in Council's programmes; and have thus ensured the avoidance of wasteful duplication of effort and the pooling of human and financial resources, thus economising on the costs of scientific activities. This latter type of cooperation between Council and international organisations is in a separate paper on modalities of scientific cooperation; and has usually taken the form of assistance in the organisation of workshops, in the funding especially of non-Commonwealth participants, and in representation. There has not been much collaboration between Council and international institutions in research activities mainly because of Council's previous programme emphasis on technology transfer. Nevertheless, Council's previous experience suggests that cooperation with international institutions has considerable potential especially for research and training, for international visibility, for focussing programme activities, and for enhancing its credibility in managing scientific programmes. This potential is vast because of the large number of and the numerous requests received from international institutions. It is necessary that Council should first identify those international institutions with similar interests and activities, and then explore the specific areas and modalities for cooperation.

(f) International Centres

16. Centres for scientific research and training with an international dimension in specific subject areas, have been invaluable for enhancing scientific and technological capability of member countries in Council's past programmes. For example, one senior scientist of the Physics and Engineering Laboratory (PEL) of DSIR, New Zealand coordinated and managed the Asia-Pacific Metrology Programme during 1977 - 80, liaising with participating countries, assisting them with the building of their infrastructure and training of personnel, and serving as the custodian of a caesium beam travelling clock. All these costs were provided by the New Zealand government, while Council only met the costs of overseas travel and subsistence. The Physics and Engineering Laboratory of DSIR, New Zealand, thus functioned as the regional centre for Council's metrology programme. Similarly, the National Measurement Laboratory (NML) of CSIRO, Australia, under its senior scientist, functioned as the regional centre for this metrology programme during 1980 - 83, with financial aid from the Australian Development Assistance Bureau (ADAB); the Regional Research Laboratory (RRL) of CSIR, Hyderabad, India, under its director, functioned as the regional centre for the Water Hyacinth Project during 1979 - 83, with the support of Indian funds; and the National Council of Science and Technology (NCST), Kenya, in association with a senior scientist, functioned as the regional centre for the African Energy Programme, with financial aid mainly from the Overseas Development Administration (ODA) UK.

17. These previous experiences in Council's programmes thus show that national institutions have functioned as de facto regional centres and have been instrumental in ensuring successful programmes. Needless to say, the effectiveness of these centres has been dependent on the leadership and vision of able senior scientists, on international team-building, on the availability of both national and international funds to support the programme, and on the commitment of the lead institution towards this larger regional role. The importance of scientific leadership and regional centres has been recognised by the 1981 Working Group.

18. A variety of programmes in the Commonwealth Secretariat also utilise or develop regional centres: The Fellowship and Training Programme uses 13 national or regional institutions for regional training, at a cost of about £600,000 per annum (20% of budget). The Commonwealth Youth Programme operates three regional centres for its training activities. The Medical Programme uses two regional health secretariats in Africa and one in the Caribbean region for regional consultation and training.

19. Regional centres for research, training and information exchange in specific subject areas would thus be useful for enhancing scientific cooperation beyond project networks, provided they were based around capable scientists and had the support of the host and member countries. Their potential and identification would require consultation among expert scientists; their designation may require some protocol; and their function would require additional financial resources for exchange of personnel, research, training and information dissemination, depending on the nature of each centre. Such a centre may take one of several forms, such as:

a) a training centre with Council providing some fellowships to an existing laboratory or institute;

b) a research and training centre with Council providing some research grants, support staff and fellowships to an existing laboratory or institute; and

c) a new and independent centre for research, training and information dissemination, with Council providing staff; facilities, administration and fellowships.

While the first two varieties of regional and international centres are quick to establish and enhance a national facility, they may generate local conflicts in policy objectives, salary scales and designations. They are nevertheless worthwhile from Council's past experience especially to enhance institution-building in cooperative programmes. The last variety is very expensive, has a longer gestation period, and is more difficult to sustain.

(C) FUTURE PROSPECTS

20. Council's past experience suggests that its programmes for generating local scientific and technological capability may be enhanced by institution-building through:

a) establishing project networks on specific subject areas,

b) involvement of government institutions,

c) involvement of universities,

d) involvement of industrial, private and non-governmental institutions,

e) collaboration with international institutions, and

f) identifying regional and international research and training centres based on existing local institutions, and around capable scientists.

Of these, institution-building appears most effective on a network basis. These networks would be catalytic if based around capable scientists especially from universities and non-governmental bodies, besides governmental institutions. They appear best secured if such scientists have international outlooks for scientific cooperation, or are based in international research and training centres.

TABLE 1

GOVERNMENTAL INSTITUTIONS (EXCLUDING UNIVERSITIES)
COLLABORATING IN COUNCIL'S PROJECT NETWORKS (1977 - 83)

Type	No	%
Regional Intergovernmental Organisations (R)	9	5
Government Department with or without research laboratories (G)	88	51
Semi-autonomous Organisations with or without research laboratories (S)	9	5
National Science or Research Councils with advisory or policy-making capacity (CP)	7	7
National Science Council with functional research laboratories (CL)	5	
Research and Technical Establishments (L)	56	32
TOTAL	174	100

TABLE 2 UNIVERSITIES COLLABORATING IN COUNCIL'S PROJECT NETWORKS

Country/University	Programme Area	Mode of Collaboration
AUSTRALIA		
University of Western Australia	Renewable Natural Resources	Information exchange on medicinal plants
BANGLADESH		
University of Agriculture, Mymensingh	Rural Technology	R & D on rice bran oil
Dhaka University	- do -	R & D on water hyacinth
Engineering University	Energy	R & D on water hyacinth, biogas and rural energy survey and Regional Programme/ Project Coordination
HONG KONG		
Chinese University of Hong Kong	Renewable Natural Resources	R & D medicinal plants, Regional Information Liaison Centre on Medicinal Plants
BRITAIN		
Reading University	Rural Technology	Assistance with programme/project planning
	Energy	- do -
Imperial College	Energy	- do -
INDIA		
Jawaharlal Nehru Technical University	Rural Technology	R & D fixed roof biogas using water hyacinth as a feed material

UNIVERSITIES COLLABORATING IN COUNCIL'S PROJECT NETWORKS

Country/University	Programme Area	Mode of Collaboration
JAMAICA University of the West Indies	Energy	Programme Coordination
CYPRUS Higher Technical Institute (Note: In Cyprus this is the highest institution of learning)	Energy	R & D on Solar Cooling
FIJI University of the South Pacific	Rural Technology	R & D on medicinal plants
KENYA Kenyatta University College	Energy	R & D on solar crop drying
University of Nairobi	Energy	R & D on solar crop drying Regional Programme Coordination
MALTA University of Malta		Overall coordination of CSC activities
MAURITIUS University of Mauritius	Energy	R & D on biogas
PAPUA NEW GUINEA University of Technology	Rural Technology	- Development of light engineering industry for agriculture - Demonstration of activated carbon from coconut shell

UNIVERSITIES COLLABORATING IN COUNCIL'S PROJECT NETWORKS

Country/University	Programme Area	Mode of Collaboration
SRI LANKA University of Peradeniya	Rural Technology	R & D on biology of water hyacinth
TANZANIA University of Dar es Salaam	Energy	R & D on solar crop drying
TRINIDAD AND TOBAGO University of the West Indies	Renewable Natural Resources	R & D and survey of medicinal plants in Trinidad and Tobago
UGANDA Makerere University	Energy	R & D on solar crop drying, biogas and solar cooling and Regional Project Coordination
ZAMBIA University of Zambia	Energy	R & D on charcoal production and utilisation and Regional Project Coordination

NATIONAL INSTITUTIONS INVOLVED IN COUNCIL'S PROGRAMMES (1977 - 83) APPENDIX A

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Australia	CSC Member	Policy Division Department of Science & Technology Canberra (G)	Overall Programme coordination
		National Measurement Laboratory (L) Lindfield	Industrial Support - Coordination of Asia-Pacific Metrology Programme
		National Standards Commission (L) Norty Ryde	Industrial Support - information exchange
		CSIRO Division of Entomology Long Pocket Laboratories (L) Queensland	Renewable Natural Resources, Biological Control of Water Hyacinth
		Bureau of Mineral Resources (G)	Mineral Resources
Antigua	Non-Member	East Caribbean Common Market Secretariat Gunthropes (R) [Not a national body, but coordinates activities on behalf of its member states (small islands)]	Industrial Support - Programme Coordination
Bahamas	CSC Member	Ministry of External Affairs (G) Nassau	Overall Programme Coordination
Bangladesh	- do -	Science & Technology Division (G) Dhaka	Overall Programme Coordination
		Geological Survey of Bangladesh (G)	Mineral Resources
		Central Testing Laboratories (L) Dhaka	Industrial Support
		Bangladesh Standards Institution (L) Dhaka	Industrial Support

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Bangladesh	CSC Member	Bangladesh Small & Cottage Industries Corporation, Dhaka 2 (G)	Rural Technology - Rice Bran Oil Extraction, Leaf protein as chicken feed, Light Engineering Industry for Agriculture
		Housing & Building Research Institute Dhaka (L)	Rural Housing
		Unani Ayurvedic Research Institute (L) Dhaka 5	Renewable Natural Resources - Medicinal plants
		Bangladesh Steel & Engineering Corp. (G) Dhaka 2	Rural Technology - Development of Prime Movers
Barbados	- do -	Ministry of Agriculture Food and (G) Consumer Affairs, St Michael	Programme Coordination
		Ministry of Finance and Planning (G) Barbados National Standards (L) Institution, St Michael	Mineral Resources, Industrial Support (Regional Programme Coordination)
		Caribbean Development Bank (R) St Michael	Energy - Programme Coordination
		Barbados Institute of Management (G) & Productivity, St Michael	Energy
		Caribbean Meteorological Institute (R)	Energy
Botswana	- do -	Geological Survey Department (G) Lobatse	Programme Coordination
		Ministry of Commerce & Industry (G) Gaborone	Industrial Support

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Botswana	CSC Member	Botswana Technology Centre (L) Gaborone	Energy
		Ministry of Mineral Resources (G) and Water Affairs, Gaborone	Energy
Britain	- do -	Health & Natural Resources Dept. (G) Overseas Development Administration London	Programme Coordination
		Institute of Geological Sciences (L)	Mineral Resources
		National Physical Laboratory (L) Teddington	Industrial Support - Assistance with Programme planning and evaluation
		Department of Trade, Legal Metrology (L) Branch, Metrology, Quality & Standards Division London	Industrial Support - Assistance with Programme planning and evaluation
		Building Research Station (L) Watford WD2 7JR	Rural Technology - Rural Housing Survey
		Tropical Products Institute (L) London	Energy (Information exchange charcoal production)
Belize	Non-Member	Ministry of Trade, Industry, (G) Cooperatives, Belmopan	

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Canada	CSC Member	International Division Ministry of State for Science & Technology Ontario (G)	Programme Coordination
		Geological Survey of Canada (G)	Mineral Resources
Cyprus	- do -	Ministry of Agriculture & Natural Resources, Nicosia (G)	Programme Coordination
		Cyprus Organisation for Standardization and Quality Control, Nicosia (L)	Industrial Support, Regional Coordination Information exchange
China	Non-member	State Bureau of Metrology, Beijing (L)	Industrial Support
Fiji	Non-member	Ministry of External Affairs (G)	Programme Coordination
		Ministry of Commerce & Industry, Suva (G)	Industrial Support
		Department of Mineral Development (G)	Mineral Resources
		Ministry of Energy, Suva (G)	Information Exchange on Rural Energy
Ghana	CSC Member	Council for Scientific & Industrial Research, Accra (CL)	Programme Coordination
		Geological Survey Department (G)	Mineral Resources
		Ghana Standards Board, Accra (L)	Industrial Support
		Food Research Institute, Accra (L)	Energy
		Forest Products Research Institute (CSIR) Kumasi (L)	Renewable Natural Resources

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Grenada	CSC Member	The Science & Technology Council of Grenada, Tanteen, St George's (CP)	Programme Coordination and participation
		Ministry of Industrial Development and Fisheries (G)	Renewable Natural Resources
Guyana	- do -	National Science Research Council (CL)	Programme Coordination and participation (Energy, Industrial Support)
		Institute of Applied Science and Technology (L)	Industrial Support
		Caribbean Community Secretariat, Georgetown (R)	Industrial Support
		Department of Geological Survey and Mines (G)	Mineral Resources
The Gambia	Non-member	Ministry of Finance & Trade, Banjul (G)	Programme Coordination
		Ministry of Economic Planning, Banjul (G)	Industrial Support
		Department of Hydrometeorological Services, Banjul (G)	Energy
West Germany	Non-member	Physikalisch-Technische Bundesanstalt Buraunschweig (L)	Industrial Support
Hong Kong	Dependent Territory	Royal Observatory, Kowloon (L)	Industrial Support
		Government Secretariat, Economic Services Branch (G)	Programme Coordination

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Hong Kong	Dependent Territory	Ministry of Trade, Industry & Customs, Kowloon (G)	Industrial Support
India	CSC Member	Council for Scientific & Industrial Research, New Delhi 110001 (CL)	Programme Coordination
		Geological Survey of India (G)	Mineral Resources
		National Physical Laboratory New Delhi (L)	Industrial Support
		Regional Research Laboratory Hyderabad (L)	Renewable Natural Resources - Regional Coordination of Water Hyacinth Project
		Regional Research Laboratory Jorhat (L)	- Assistance with Coordination of Rural Technology Programme
		Ministry of Industry and Civil Supplies, New Delhi (G)	Coordination of Rural Technology
		Central Food Technological Research Institute, Mysore (L)	Coordination of Rural Technology
		Central Building Research Institute, Uttar Pradesh (L)	Coordination of Rural Technology
		Central Institute of Medicinal and Aromatic Plants, Lucknow (L)	Renewable Natural Resources
		National Environmental Engineering Research Institute, Nagpur (L)	Rural Technology
		Central Leather Research Institute, Madras (L)	Renewable Natural Resource
		Central Mechanical Engineering Research Institute, West Bangal (L)	Rural Technology

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
India	CSC Member	Khadi and Village Industries Commission (S)	Energy
		Regional Centre for Technology Transfer (R)	Rural Technology
Indonesia	Non-Commonwealth	National Institute of Instrumentation, Bandung (L)	Industrial Support
Jamaica	CSC Member	Scientific Research Council, Kingston (L)	Programme Coordination and participation in Energy and Renewable Natural Resouces
		The Jamaican Bureau of Standards, Kingston (L)	Industrial Support
		Geological Survey Department (G)	Mineral Resources
		Ministry of Mining & Energy (G)	Energy
Japan	Non-Commonwealth	International Research & Development Cooperation Division Agency of Industrial Science & Technology (G)	Industrial Support
		National Research Laboratory of Metrology (L)	Industrial Support
Jordan	Non-Commonwealth	Arab Organisation for Standardization and Metrology (R)	Industrial Support
Kenya	CSC Member	National Council for Science & Technology (CP)	Programme Coordination
		Ministry of Energy (G)	Energy
		Mines and Geological Department (G)	Mineral Resources

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Kenya	CSC Member	African Regional Organisation for Standardization, Nairobi (R)	Industrial Support (Programme Coordination)
		Kenya Bureau of Standards, Nairobi (L)	Industrial Support (Programme Coordination)
		Kenya Forest Department (G)	Energy
Korea	Non-Commonwealth	Korea Standards Research Institute, Chung (L)	Industrial Support
Lesotho	CSC Member	Technical Division, Appropriate Technology Unit Ministry of Cooperatives & Rural Development, Maseru (G)	Programme Coordination
		Department of Mines (G)	Mineral Resources
		Central Planning & Development Office Ministry of Planning & Statistics (G)	Industrial Support
Malawi	- do -	National Research Council of Malawi (CP)	Programme Coordination
		Geological Survey Department (G)	Mineral Resources
		Malawi Bureau of Standards (L)	Industrial Support
Malaysia	- do -	Ministry of Science Technology & Environment (G)	Porgramme Coordination

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Malaysia	CSC Member	Federal Geological Survey Department (G)	Mineral Resources
		Standards & Industrial Research, Institute of Malaysia (L)	Rural Technology, Industrial Support
Malta	- do -	University of Malta (L)	Programme Coordination
		Oil Exploration Division, Prime Minister's Office (G)	Mineral Resources
		Department of Industry (G)	Industrial Support
		ENEMALTA Corporation (S)	Energy
Mauritius	- do -	Ministry of Economic Planning & Development (G)	Programme Coordination
		Mauritius Standards Bureau (L)	Industrial Support
New Zealand	- do -	Department of Scientific & Industrial Research (G)	Programme Coordination
		Geological Survey of New Zealand (G)	Mineral Resources
		Physics & Engineering Laboratory (L)	Industrial Support
Nigeria	- do -	Federal Ministry of Science & Technology (G)	Programme Coordination
		Geological Survey Department (G)	Mineral Resources
		Nigerian Standards Organisation (L)	Industrial Support
		OAU/STRC Secretariat (R)	Programme Coordination-- Renewable

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Niger	Non-Commonwealth	Office Nigerienne Poon, La Energie Solaire (Onersol) (G)	Energy
Nepal	Non-Commonwealth	Department of Mint, Weights & Measures (G)	Industrial Support
Papua New Guinea	CSC Member	Ministry for Science, Culture & Recreation (G)	Programme Coordination
		Department of Minerals and Energy (G)	Mineral Resources
		Department of Labour & Industry (G)	Industrial Support
		Community Based Programme, Manus Province (G)	Rural Technology
		South Pacific Appropriate Technology Institute (S)	Rural Technology
		Department of Works & Supply (G)	Rural Technology
Pakistan	Non-Commonwealth	National Physical & Standards Laboratory (L)	Industrial Support
Philippines	Non-Commonwealth	National Institute of Science & Technology (L)	Industrial Support
Rwanda	Non-Commonwealth	Centre d'Etudes et d'Application de l'Energie au Rwanda (L)	Energy
		Service Meteorologique (G)	Energy

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Seychelles	CSC Member	Ministry of Planning & Development (G)	Programme Coordination
		Seychelles Electricity Corporation (S)	Energy
		Department of Works (G)	Rural Technology
		Victoria Hospital (G)	Renewable Natural Resources
		Anse aux Pins State Farm (S)	Energy
		Seychelles Housing Development Corp. (S)	Rural Technology
Sierra Leone	- do -	Ministry of Education (G)	Programme Coordination
		Geological Survey Department (G)	Mineral Resources
		Weights and Measures Department (L)	Industrial Support
		Ministry of Energy & Power (G)	Energy
Singapore	- do -	Singapore Science Council (CP)	Programme Coordination
		Public Works Department (G)	Mineral Resources
		Singapore Institute of Standards & Industrial Research (L)	Industrial Support
Solomon Islands	Non-member	Geological Survey Department (G)	Mineral Resources

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Sri Lanka	CSC Member	Natural Resources, Energy & Science Authority of Sri Lanka (G)	Programme Coordination
		Geological Survey Department (G)	Mineral Resources
		Weights & Measures Division Department of Price Control (L)	Industrial Support
		Industrial Development Board (G)	Rural Technology
		National Engineering Research & Development Centre (L)	Rural Technology
		Sri Lanka Export Development Board (S)	Rural Technology
		State Engineering Corporation (S)	Rural Technology
		National Water Supply & Drainage Board (S)	Rural Technology
		Ceylon Electricity Board (S)	Energy
		Medical Research Institute (L)	Renewable Natural Resources
Swaziland	- do -	National Research Council (CP)	Programme Coordination
		Geological Survey and Mines Department (G)	Mineral Resources
Western Samoa	Non-member	Office for Tokelau Affairs (G)	Programme Coordination
Tanzania	CSC Member	Tanzania National Scientific Research Council (CL)	Programme Coordination

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
Tanzania	CSC Member	Ministry of Water, Energy and Minerals (G)	Mineral Resources
		Tanzania Bureau of Standards (L)	Industrial Support
		Office of the Director of Forestry (G)	Energy
		Ministry of Health (G)	Renewable Natural Resources
Trinidad and Tobago	- do -	National Council for Technology in Development (CP)	Programme Coordination
		Ministry of Energy and Natural Resources (G)	Mineral Resources
		Trinidad & Tobago Bureau of Standards (L)	Industrial Support
Tonga	Non-member	Prime Minister's Office (G)	Programme Coordination
Thailand	Non-Commonwealth	Ministry of Science, Technology & Energy (G)	Industrial Support
		UN Economic Commission for Asia-Pacific (R)	Industrial Support
Uganda	CSC Member	Ministry of Planning & Economic Development (G)	Programme Coordination
		Department of Geological Survey and Mines (G)	Mineral Resources
		Weights & Measures Department (L)	Industrial Support
		Nakawa Forestry Research Station (G)	Energy
Vanuatu	Non-member	Geological Survey Department (G)	Mineral Resources

Country	Classification	Institution/Organisation (Type)	Nature of Involvement/Programme Area
U S S R	Non Commonwealth	USSR State Committee for Standards (G)	Industrial Support (Information Exchange)
Zambia	CSC Member	National Council for Scientific Research (CL)	Programme Coordination
		Geological Survey Department (G)	Mineral Resources
		Zambia Standards Institute (L)	Industrial Support
		Forest Department (G)	Energy
Zimbabwe	CSC Member	Scientific Council of Zimbabwe (CP)	Programme Coordination
		Geological Survey Department (G)	Mineral Resources
		Standards Association of Central Africa (L)	Industrial Support
		Department of Research and Specialist Services (G)	Renewable Natural Resources
		Ministry of Industry and Energy Development (G)	Energy

PROGRAMME FINANCE FOR SCIENTIFIC COOPERATION IN THE COMMONWEALTH

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(A) INTRODUCTION

1. The cooperative science programme of the Commonwealth Science Council (CSC) launched in 1975, has demonstrated the feasibility of scientific cooperation among member countries in enhancing their scientific and technological capacities. Several project activities were undertaken under three programme areas which concerned transfer of technology, already proven but inadequately utilised for rural development, standardization and metrology, and mineral resources and geology. The shift in Council's programme emphasis to the application of science for development means that the enhancement of professional scientific and technological expertise in Commonwealth countries must be undertaken through cooperative research, training and information dissemination. The realisation of this emphasis thus involves an expanded programme of scientific cooperation within the Commonwealth, for which additional financial resources will be needed. Council has not fully addressed the issue of programme finance, in particular the different modes of finance available. This paper attempts to summarise Council's programme finance over the last five years. It suggests possibilities for additional funds for implementing Council's expanded cooperative and scientific programme, cognisant of present world-wide financial difficulties and the role of other international bodies involved in research and science.

(B) ANALYSIS AND INTERPRETATION

2. Funds for Council's programmes are currently derived from four sources:

   (a) the Regular Budget (Annually),

   (b) the Project Fund (on an *ad-hoc* basis),

   (c) the Commonwealth Fund for Technical Cooperation (CFTC), and

   (d) external sources.

(a) Regular Budget

3. The Regular Budget comprises contributions from member countries (at present numbering 32) on an agreed scale, in which five countries (Australia, Britain, Canada, India and New Zealand) contribute 82.4% while the remaining countries 17.6% of the Budget. This Budget has been modest over the last five years (£193,000 - £315,000) (Table 1). There has been very little budgetary growth from year to year, and in real terms this has been insignificant.

Table 1 : CSC Regular Budget (1979 - 84)

Year	Amount (£)	% increase over previous year	Annual inflation rate (UK)
1979 - 80	192,850	-	18.9
1980 - 81	232,740	17.1	11.1
1981 - 82	260,000	10.5	8.9
1982 - 83	286,000	9.1	3.9
1983 - 84	315,000	9.2	-

4. This Budget is designed specifically to meet the administrative costs of Council's secretariat in London, since programme funding is provided by the Commonwealth Fund for Technical Cooperation (CFTC) and other agencies. Nevertheless, it has been possible to allocate a small proportion (5.1%, £16,000) to Commissioned Studies (Table 2). Programme finance is not included in the Regular Budget because of the anticipated provision of such funds by the Commonwealth Fund for Technical Cooperation under the agreements forming the Memorandum of Understanding between the Council and the Commonwealth Secretariat. In any case, this Regular Budget has not been able to include major costs associated with project activities such as travel of participants, equipment and consumable supplies, fellowships, project network meetings and programme advisory meetings, although some small provisions exist for the last (eg London Management Committee, Commonwealth Committee for Mineral Resources and Geology).

Table 2
1983 - 84 CSC Regular Budget in terms of Project and Administration Costs*

Item	Cost (£)	% of Total
Commissioned Studies	16,000	5.1
Total Project		5.1
Professional Salaries	92,700	29.4
Management and Support Services	206,300	65.5
Total Administration		94.9
TOTAL	315,000	100.0

(*Excluding Commonwealth Secretariat contributions towards two professional and one support staff salaries)

5. One method of increasing programme activities would be to provide funds from the Regular Budget of Council which would need to be increased to accommodate administrative costs associated with programme development and management, project coordination, programme funding and institution-building. It cannot be envisaged that the Regular Budget could be increased to take over those areas of activities currently supported by other sources, but there is a case for providing funds from the Regular Budget for those activities which are difficult to fund from elsewhere. These activities already include:

(a) a continuing and expanded allocation for pre-project Commssioned Studies to initiate project development and evaluation through expert consultation, on the basis of the £16,000 revised allocation in 1983 - 84 and a further sum of £20,000 used for this purpose in 1983 - 84 from the Project Fund; and

(b) an expanded allocation for project group network and programme advisory meetings, on the basis of the £1,460 allocation in 1983 - 84 for the London Management Committee (LMC) and the Commonwealth Committee on Mineral Resources and Geology (CCMRG) meetings, and of the £23,500 allocation in 1982 - 83 by CFTC for steering committee meetings of previous programmes and projects, which is now not available.

6. Activities not currently supported by the Regular Budget, but which provide good possibilities for scientific development include:

(a) a new allocation for meeting the costs of some technical activities at research laboratories and units involved in Council's programmes, in order to enhance institution-building and institutional collaboration;

(b) a new allocation for temporary support or supervisory staff at some laboratories or centres, involved in research, training and information dissemination as and when necessary for project development around good capable scientists; and

(c) a new block allocation for temporary support staff and administrative costs for a regional research and training laboratory or centre in a specific area of science, and based around a team of good capable scientists.

(b) Project Fund or Programme Budget

7. The Project Fund consists of unexpended balances from Council's Regular Budget, which are held in a separate account established under the provisions for programme finance in the Memorandum of Understanding on the Council. The sum in this Fund is an unpredictable quantum, and its growth up to 1981 - 82 has been somewhat erratic (Table 3). The net sum available at the end of each year is the gross balance less some unpaid contributions from member countries; and even this net sum cannot be utilised fully because of the need for a threshold cash flow position to operate Council's secretariat. Although Council has no funds for programme activities, this Project Fund has contributed modestly to programme development, fellowships, equipment purchase, and to complement regular and other forms of programme finance.

Table 3
The Project Fund 1975 - 82 and the
Effect of Outstanding Contribution

Fiscal Year	Cumulative Fund Balance (£)	Cumulative Total of Outstanding Contributions (£)	Net Cumulative Fund Balance (£)
1975 - 76	15,262	3,158	12,104
1976 - 77	54,011	5,724	48,287
1977 - 78	72,619	11,223	61,396
1978 - 79	60,211	21,780	38,422
1979 - 80	93,447	20,977	72,470
1980 - 81	120,208	56,184	64,024
1981 - 82	157,258	80,645	76,613

8. Provisions exist in the Memorandum of Understanding on the Council for a Programme Budget, but this is envisaged on the basis of external donations and miscellaneous income. There is no provision for direct contributions by member countries towards the Programme Budget, although the Project Fund informally and indirectly resembles this. In view of Council's shift in programme emphasis from technology transfer to the application of science to technology, it appears desirable for Council to have its own modest Programme Budget which would provide the "seed" money or "core" funds for launching Council's programmes. Such a provision would rely on voluntary contributions towards programmes by Council members, and support has been indicated for this mode of programme finance by some Council members.

(c) Commonwealth Fund for Technical Cooperation

9. The Commonwealth Fund for Technical Cooperation (CFTC) has been the regular and major source of programme funds as indicated by the Secretary-General of the Commonwealth when Council's Memorandum of Understanding was adopted by the Heads of Government in 1975. During 1979 - 84, the CFTC allocations to Council's programme activities have been increasing annually in amount (Table 4). Nevertheless, allocations to Council's programmes have been comparable to other functional Divisions of the Commonwealth Secretariat.

Table 4
CFTC Allocations to CSC Programme 1979 - 84

Year	CSC allocation (£)	% increase over previous year	% of total CFTC allocation to all functional divisions	% share of total CFTC funds
1979 - 80	113,000	-	24.7	1.02
1980 - 81	138,200	18.1	24.6	1.17
1981 - 82	135,500	(-) 0.02	19.1	0.95
1982 - 83	150,000	9.7	18.5	0.85
1983 - 84	205,000	36.7	21.6	1.03
TOTAL	741,700			

10. CFTC funds for functional Divisions of the Commonwealth Secretariat, as well as those allocated to Council, are restricted to multilateral training needs (eg course, seminars, workshops) of member countries. They were once available for programme development and project management meetings of Council, but are no longer available for this purpose. They are not available for research cooperation unless this has a training element (eg internship, supervision), nor for the purchase of scientific equipment. Since CFTC's budget is anticipated to grow modestly, it would be reasonable to expect a modest increase in CFTC's contributions to the training components of Council's programmes, with the accommodation of those training elements involved in research cooperation. However, there would be no funds available from CFTC for programme development, project coordination, equipment, consumable materials and fellowships, to enhance cooperative research and training.

11. CFTC spends another 4 - 10 million pounds annually on projects related to science and technology (Table 5), in response to requests for technical assistance from member countries in the Commonwealth. Most of these funds are allocated to consultants, technical cooperation and to education and training. Technical cooperation largely embodies the establishment and rehabilitation of manufacturing industries. Although there has been a three-fold increase in CFTC expenditure on science and technology-related projects, and these represent an order of magnitude above CFTC allocations for Council's programmes, it is unlikely that any of these funds can be significantly diverted towards Council's programmes, because of the responsive role of CFTC and because of the differences in priority between national central agencies (eg treasuries, economic planning units) and national science authorities (eg ministries, councils).

Table 5
CFTC Expenditure on Technical Assistance
Related to Science and Technology (1981 - 83)

	Total (£)	Percentage (%)
Formal Education	2,396,000	17
R & D Training:		
Through from the initial idea, to setting up 'in-house' training and research in industry	450,000	3
Consultancy:		
Advice & Short term attachments to firms/ projects (2/3 years)	5,650,000	42
Technical Cooperation:		
Mostly IDU Setting up and establishing industry	4,917,000	36
Others:		
Establishing Training Centres Lectures Attendance of Meetings	318,800	3
TOTAL	13,608,800	100

(d) External Funds

12. Two major external sources, the Overseas Development Administration (ODA) of Britain and United Nations Environment Programme (UNEP), have provided funds to specific projects during 1979 - 84 (Table 6). Besides, some minor grants have been received from the Commonwealth Foundation, United Nations Centre for Human Settlements (UNCHS), and United Nations Educational Scientific and Cultural Organisation (UNESCO). These amount to less than 40% of total funds for Council's programmes; and are unlikely to increase on a regular basis because of the coincidence needed between Council's programme priorities and that of the external sources, of the shift in Council's programme emphasis from technology transfer to the application of science to technology, and of the need for some "seed" money to demonstrate the viability of Council's programmes and projects.

Table 6
Programme Funds from External Sources

Year	ODA (£)	UNEP (£)*	External Sources Total (£)	CFTC (£)	Programme Total (£)
1979-80	-	10,719	10,419	113.000	123.719
1980-81	23,091	24,566	47,657	138,200	185,857
1981-82	78,190	48,563	126,753	135,500	262,253
1982-83	120,898	76,159	197,057	150,000	347,057
1983-84	71,700	13,245	84,945	205,000	289,945
	293,879	173,252	467,131	741,700	1,208,831
(%)	(24.3)	(14.3)	(38.6)	(62.4)	(100)

(* Exchange rate £1 = US$1.51)

13. In addition, substantial programme funds have been contributed by member countries in the form of local costs for meetings, workshops, training courses and research; however, the extent of support varies for each country and is not a fully quantifiable sum. For example, A$300,000 over a three-year period to support activities of the Asia-Pacific Metrology Programme coordinated by Australia; these funds were managed by Australia and details are not available to Council's secretariat. Most of the national contributions are "hidden" in the budgets of participating institutions.

14. International funds for scientific research especially in developing countries are generally scarce. Universities and scientific institutions in developing countries are usually entirely dependent on government grants which barely cover their administrative and management costs, leaving little or no funds for research activities. In some cases, a national science infrastructure exists so that research grants become available occasionally through National Science Councils, University Grants Committees and such bodies. Again, these funds originate from the national treasury and are inadequate for sustained research in sciences applicable to technology. Furthermore, industrial or private foundations are not well established especially in developing countries. The chronic shortage of foreign currency in those countries hinders overseas training, information acquisition, and procurement of equipment and consumable materials. Research in developing countries is therefore unable to generate a momentum necessary for enhancing indigenous capabilities and reducing technological dependence. External funds are therefore necessary for catalysing scientific research, training and information dissemination in developing countries until national economies can give it their priority concern.

15. Council's successful projects in the past were those with adequate external funds for research, training and information dissemination, such as the Water Hyacinth Project supported with UNEP funds, the Asia/Pacific Metrology Programme with ADAB funds, the Rural Energy Survey with CFTC funds, the African Energy Projects with ODA funds, and the various training and information dissemination activities with CFTC funds. Funds for research and development activities in Council's programmes have been difficult to obtain even though the research and development activities have been directly linked to the enhancement of indigenous scientific and technological capability especially in developing countries, and thus have had a developmental context. The external funding sources have financed those activities directly related to their priority interests; and only a small fraction of Council's research and development activities have attracted external funds. CFTC is not able to finance scientific research though able to finance training and information dissemination relevant to development. There is a need therefore to explore external funding for enhancing, in a variety of ways, the scientific and technological capacities of member countries through Council's programmes.

16. International funds abound for large scale research and implementation programmes and projects (Table 7); while effective in developing infrastructure especially in governmental systems, these funds are less effective in generating relevant research especially around good individual scientists. Council has not sought these funds hitherto, and would be unable to do so since these funds are usually given to governments. A variety of funds also exist for small-scale research projects. These are effective in stimulating research but often are ineffective in developing infrastructure. The Council has had some experience in obtaining these grants and should continue to do so. Only a few agencies internationally finance individual research efforts. While effective in reaching good individual scientists and generating interesting research, these have not been effective in developing infrastructure. The Council has not utilised this avenue of research financing, hitherto. It would appear necessary therefore for Council to diversify its sources of external funds for research to keep in place good individual scientists and to develop the infrastructure necessary for giving science and technology an endogenous and local momentum.

17. A variety of intergovernmental, national and multilateral, non-governmental and private organisations provide funds for scientific and technological research, training and information dissemination (Table 8). Intergovernmental organisations financing science and technology activities such as the UN Financing System for Science and Technology for Development, (UNFSSTD), the United Nations Development Programme (UNDP), the European Economic Community's Science and Technology Development Programme (EEC) and the Commonwealth Fund for Technical Cooperation (CFTC), require requests for funds to be sent through appropriate government channels. This makes them virtually unavailable for Council's scientific and technological programmes since (a) countries may have different priorities in comparison to Council's programmes, (b) these organisations may have their own priorities in comparison to Council's programmes and to member countries, and (c) there will be the need for advanced planning and lengthy negotiations. Council needs to develop a closer liaison with national central agencies which are the contact points with these funds, and with some of these organisations particularly the EEC, UNDP, UNEP, UNESCO and the UN University where funds appear available for collaborative projects. With these latter organisations, Council should continue seeking direct funds on behalf of participating member countries for specific projects. With CFTC, Council has a special relationship which could be developed further.

18. Several national and multilateral organisations (Table 9) such as Australian Development Assistance Bureau (ADAB), Canadian International Development Agency (CIDA), UK's Overseas Developmnet Administration (ODA) and International Development Research Centre (IDRC) of Canada, have supported Council's activities. All these also require requests from member countries for bilateral or multilateral financing. Council should continue to seek funds from these organisations, locating additional sources within this group and developing special modalities such as twinning arrangements between institutions under IDRC and CIDA. Their potential in Council's expanded programme of scientific cooperation is promising.

19. Among non-governmental organisations (Table 10), only the Commonwealth Foundation has hitherto supported Council's training activities through fellowships, participation in meetings and resource persons for professional development. These organisations should be further explored for fellowships, exchange visits, research, etc, especially bodies like the Royal Society of London which receives subventions for Commonwealth activities, and the International Foundation for Science (IFS) which supports individual research efforts.

20. Hitherto, no serious attempts have been made to seek funds from private organisations, (Table 11). Although these may not like to extend support to an intergovernmental body like Council, they may consider appropriate and specific project requests fitting with their objectives, from scientists, participating in Council's projects. Several of them like the Volkswagen Foundation, the Ford Foundation, the Rockefeller Foundation, the Toyota Foundation, the Leverhulme Trust and Alexander Von Humboldt Foundation support individual research projects. Council needs to spend much effort in matching these organisations with suitable scientists.

21. Therefore, Council needs to explore a variety of approaches for seeking funds from external agencies for research, training and information dissemination. In particular, it should develop a special relationship with financing institutions within the Commonwealth family such as the Commonwealth Fund for Technical Cooperation (CFTC) and the Commonwealth Foundation, with aid agencies in Commonwealth Countries such as the Canadian International Development Agency (CIDA) and the Overseas Development Administration (ODA) UK, with non-governmental and private organisations in Commonwealth countries such as the International Development Research Centre (IDRC) and the Royal Society, and with other international, national and private organisations such as UNEP and UNDP, and the Leverhulme Trust. The prospects for research funds appear good if the proposals embody a clear scientific focus especially in energy, earth sciences and agriculture (sensu lato) related to the tropical and arid zones, and promote bilateral linkages between the industrialised and developing countries. There appears no possibility for seeking a general earmarking of funds for Council's projects by external sources.

(C) FUTURE PROSPECTS AND CONCLUSIONS

22. Although Council's programmes have attracted funds from various sources, the following salient features emerge from past experience:

    (a) CFTC is the only certain source of programme funds and these are limited to projects that have a training component and that are responsive to the needs of member countries. The role of institutions within the Commonwealth family needs to be strengthened in relation to Council's purpose.

(b) Only a small fraction of Council's projects, developed through project networks, attracted external funds so much so that programme implementation appears dependent on the priorities of funding institutions rather than the priorities of Council and member countries. While advantageous in terms of multiplier effects, this situation is not conducive to programme and project development or to the morale of scientists especially in Commonwealth developing countries.

(c) Programme and project development is frustrating without some secure financial support for an intergovernmental Science Council. This situation can be overcome by establishing a Programme Budget funded by member countries, on a voluntary basis, regularising the Project Fund and augmenting Council's Regular Budget.

(d) Council's impact in enhancing the scientific capacities of developing Commonwealth countries, in particular, have been modest because of the limitations of both programme funds and the nature of the programme. This situation can be overcome by elaborating the funding, programme development and institution-building functions of Council, and by involving good scientists in Council's programmes and projects at all levels.

23. The present level of finance is inadequate to expand Council's programme of scientific cooperation for enhancing local professional capability in science and technology, especially when such a programme emphasising the application of science to technology for development will involve scientists in cooperative research, training and information dissemination of a high quality. It would be reasonable to estimate a level of programme finance at least one to two orders of magnitude above the present level, that is more than £2 million.

24. There is therefore a need for Council to secure programme finance of sufficient magnitude as "seed money" or "core funds" so that:

(a) science may be stimulated to play a more significant role in the socio-economic development of Commonwealth countries, especially the developing countries, in comparison to other Commonwealth programmes such as that on youth;

(b) Council may be effective in stimulating the enhancement of scientific capability, especially in developing countries, according to its own priorities and the perceived needs of member countries for socio-economic development;

(c) Council may stimulate local investments in science and technology for national development, since these must exceed international resources in order to determine the direction and pace of industrial and economic development, the involvement of indigenous capabilities for endogenous innovation, and the national and international linkages between science and industry; and

(d) Council, as one of the few intergovernmental councils for science, may exercise its full complement of roles especially in project development, monitoring and coordination, programme and project funding, institution-building, specific training, information dissemination, and in science planning and policy formulation.

25. Securing capital to finance Council's programme activities involving cooperative research, training and information dissemination for enhancing indigenous scientific capability is difficult at present, because of the current global economic situation and of the advanced planning cycles of most funding bodies. Nevertheless, increase in financial resources for programme activities will not only enable more efficient planning and execution of projects but, in turn, will increase Council's performance in project implementation and its impact on development in the Commonwealth. There are four ways whereby Council's financial resources may be augmented:

(a) The annual Regular Budget of Council could be increased to accommodate allocations for pre-project Commissioned Studies to initiate project development through expert consultation; for project group, network and advisory meetings, along the lines of the London Management Committee (LMC) and the Commonwealth Committee on Mineral Resources and Geology (CCMRG) and of previous steering committee meetings for projects, in order to facilitate technical consultations; and towards administrative costs of meetings on projects at centres for scientific research and training in developing countries, in order to facilitate institution-building and institutional collaboration.

(b) Besides the annual allocation for Council's training activities from CFTC which is the only secure source of programme finance, Council should explore establishing a special relationship with CFTC, the Commonwealth Foundation and other sister institutions within the Commonwealth family possessing similar programme autonomy as Council itself.

(c) Council could establish a Programme Budget paid for by member countries according to some agreed scale of voluntary contributions. Provisions already exist for such a Budget but it would require an amendment to the Memorandum of Understanding and the agreement of member countries. This Budget would provide the "seed money" or "core" funds for Council's programmes and projects, similar to that of the Commonwealth Youth Programme (CYP), would regularise the Project Fund, and would facilitate medium-term programme development and project planning.

(d) Council could actively solicit for greater voluntary contributions and external funds for specific projects, to supplement the "seed money" or "core" funds for Council's programmes and projects. Such contributions could be in convertible currency where possible and in local currency where not. However, local currency contributions would increase management costs, and could limit choice, quality and distribution of activities. Such an approach would require a special fund-raising capacity within Council's secretariat. It could potentially create conflicts with pledges by member countries to CFTC, would require special preparation of attractive project documents, advertisements and campaigns, and would demand additional secretariat efforts for negotiations and agreements on modalities with external bodies.

26. Council's effectiveness in promoting scientific cooperation in the Commonwealth in order to enhance local scientific and technological capability, is dependent on medium-term plans, and flexibility in focusing the direction of projects to suit the wishes of member countries and their needs for socio-economic competitiveness. Such a capacity would facilitate cooperation with various funding bodies. However, it would demand some measure of financial security from Council for programme development, project implementation and project coordination. The challenges facing Council in the next two decades are thus large and complex, but not insurmountable given the will to apply science to development.

TABLE 7 : INTERNATIONAL FUNDS SUPPORTING VARIOUS TYPES OF SCIENTIFIC AND TECHNOLOGICAL ACTIVITIES

Types of Activities	Requirements and Characteristics	Range of Funding (US$ per year)	Funding Agencies Providing Support
Individual Research Efforts	- Scientific capability and creativity - Interaction with peers - Access to literature and (possibly) travel - Access to scientific equipment and materials in a limited scale - One scientist with (possibly) technical assistants - Minimum of managerial skills - 1-4 years of support	Less than $10,000	I F S
Research Projects	- Scientific and technical capability and creativity - Interaction with peers and with users of research results - Access to literature and travel - Access to specialised scientific equipment and materials in a continuous fashion - Multidisciplinary teams (eg 3-5 researchers plus assistants) - Access to (possibly) pilot plants and small scale field trials - Intermediate level of managerial skills - 2-5 years of support	$10,000 - $150,000	) Private Foundations) (Ford, Rockefeller, etc)) - SAREC) - BOSTID (AID/NAS)) - UNESCO) - UN Agencies) - UNDP) - NUFFIC) - IDRC) - CIDA) - AID) - ORSTOM) - SIDA) - GTZ) - Other bilateral agencies (Dutch, British, Belgian, Italian, etc)
Large-scale Research and Implementation Programmes and Projects (possibly including extension work, industrial implementation and training)	- Technical and scientific capability - Interaction with other research groups, farmers, industry, government agencies, international agencies, etc - Access to specialised laboratories and materials exclusively for the programme or project - Large multidisciplinary teams (eg 5-20 researchers plus assistants) - Access to pilot plants and industrial facilities, large scale field trials - High level of managerial skills and control - 4 or more years of support	More than $150,000, reaching in some cases several million dollars	) - WHO (tropical diseases)) - CGIR) - World Bank) - IFAD) - ADB) - IDB

SOURCE: F Sagasti, G Oldham, P Vorauri and P Thiongane. 1983. Evaluation of the International Foundation for Science (1974 - 1981). Fianl Report. IFS, Stockholm.

Table 8 Intergovernmental Sources of External Funds for Research

Sources	Subject Areas	Remarks
European Economic Community (EEC) Science and Technology for Development Programme 1983-86	Tropical Agriculture, Medicine, Health, and Nutrition in the Tropics	Require joint projects between laboratories in EEC member and developing countries.
Islamic Foundation for Science Technology and Development (IFSTD)	Geological Survey, Resource Mapping Oceanography, Marine Resources, Energy, Electronics, Engineering, Industry, Space Research, Water Resources, Desalination, Ecology	Confined to Muslim states and Muslim talents
Colombo Plan Bureau		Does not fund research and development; supports professional development
United Nations Development Programme (UNDP)	Various fields related to development.	Also Trust Funds for specific activities eg. Revolving Fund for Natural Resource Exploitation.
UN Financing System for Science and Technology (UNFSST)	Wide range of fields with developmental emphasis	Expects to raise core fund of US$300m during 1983-86 and a similar amount as non-core funds. Request through government channels.
United Nations Educational, Scientific and Cultural Organisation (UNESCO)	Wide range of fields in science and engineering including science policy	Raises funds through contributions by governments to its programme budget. Collaboration with UNESCO possible

Sources	Subject Areas	Remarks
United Nations University (UNU)	Various fields	Conducts work through its own programmes and projects. Collaborative activities possible
Commonwealth Fund for Technical Cooperation (CFTC)	Education, Health, Industry, Agriculture, Transport and Telecommunications, Energy, and Mass Communication	Supports developmental projects through expert advice, experts and training. Does not provide capital assistance.
North Atlantic Treaty Organisation (NATO) - Scientific Affairs Division	Various fields	Supports research scientists working within alliance countries and sponsors meetings in NATO member countries.(Common membership Britain and Canada). Supports postgraduate fellowships, collaborative research grants, advanced study/instructiona courses, advanced research workshops (non-tutorial) and international intersectoral (industry, academic and government) exchange. Also special programme for less developed NATO member countries.

Table 9 National and Multilateral Sources of External Funds for Research

Sources	Subject Areas	Remarks
The Swedish Agency for Research Cooperation with Developing Countries (SAREC)	Open and subject to scientific quality, and relevance to development problems	Support provided within the framework of bilateral agreements on research cooperation with developing countries to increase the number of qualified scientists. India, Sri Lanka, Tanzania, Zambia and Botswana have SAREC funds
Overseas Development Administration (ODA)	Wide range of fields including medicine and health, agriculture, forestry, livestock, fisheries, energy, nutrition, engineering and environment. Also supports international research programmes	Supports research aimed at gathering new knowledge, and evolving new techniques, directly related to the needs of developing countries. Emphasis on research of likely practical use in a reasonable period of time.
Swedish Commission for Technical Cooperation (SCTC)	Primarily supports international training programmes in Sweden in a number of fields including Telecommunications Management, Quality Control in Industry, Electric Power Engineering, Water Resource Development and Management in Arid and Semi-arid regions, Mining Technology, Manufacturing of Pharmachemicals, Pulp and Paper Technology, Project Management	Supports projects of interest to developing countries and to a public or private body in Sweden

Sources of External Funds for Research (Contd)

Sources	Subject Areas	Remarks
Swedish Fund for Industrial Cooperation with Developing Countries (Swedfund)		Does not fund R & D activities
Austrian Foundation for Development Research	Documentation and Information	Addressed to the Austrian public
Netherlands Organisatie Voor Internationale Ontwikkelingss arrenwerking (NOVIB)	Development Projects	Focussed on target groups of poor people in Third World countries
Australian Development Assistance Bureau (ADAB)	Wide range of fields related to development. Offers training awards on a government to government basis	A special secretariat for Science and Technology for Development has been established within the Bureau to consult direct with developing country scientists and planners to identify science, technology and research needs and the possibilities for Australian assistance.
Canadian International Development Agency (CIDA)	Operates and administers Canada's official international development assistance programme through bilateral programmes with developing countries and by financial contribution to international, governmental and non-governmental organisations	Considerable potential for twinning arrangements between institutions; must involve a Canadian institution.

Sources	Subject Areas	Remarks
International Development Research Centre (IDRC)	Agriculture, Food and Nutrition Sciences, Health Sciences, Information Sciences, Social Sciences and Communication	Public corporation created to support research, to adapt science and technology to the needs of developing countries. The Cooperative Programmes unit is of special interest as it facilitates joint activities involving R & D institutions in developing countries and Canada
Swedish International Development Authority (SIDA)	Does not focus particularly on R & D cooperation and training	Developing countries to determine their own priorities and may use aid to establish research institutions, to plan for cooperation or training with research bodies abroad

Table 10 Non-governmental Sources of External Funds for Research

Sources	Subject Areas	Remarks
International Foundation for Science (IFS)	Aquaculture, Animal Production, Food Crops, Afforestation and micorrhiza, Fermentation, and Applied microbiology, Natural Products, Rural Technology	Recipients of grants are young scientists and technologists in developing countries A project is judged on its scientific quality and its relevance to the need of the country Average size of a grant is US$7 000/year 15 Commonwealth countries are members of IFS
Royal Society of London	Different fields	New scheme to facilitate research in UK by people from developing countries is being established
Commonwealth Foundation	Wide range of fields	Assists professional cooperation and development, with a focus on the non-governmental sector
Committee on Science and Technology in Developing Countries (COSTED) of ICSU	Wide range of fields	Organises meetings and workshops, and administers a Travel Fellowship Programme to allow younger scientists from developing countries to attend scientific meetings in many regions

Table 11 Private Sources of External Funds for Research

Sources	Subject Areas	Remarks
Volkswagen Foundation	Engineering, Natural Science	Partnership with a German and a developing country laboratory
1% for Development	Development Projects	Private fund of UN officials who contribute 1% of their salary Preference to small, low-cost projects which promote self reliance through popular participation at the local level
Leverhulme Trust	Visiting professorship, academic chairs and scholarships for research and education in a wide range of fields. Research of good quality aimed at economic development	No restrictions as to the fields of study No geographical limits to eligibility No capital grants for building, equipment etc Unwilling to support projects in medicine or natural sciences
Battelle Memorial Institute	R & D, Management, and Education Services	Undertakes contract work for sponsors

Sources	Subject Areas	Remarks
Ford Foundation	R & D preference to projects in agricultural technology	Provides funds for educational and developmental research, and experimental efforts designed to produce significant advances or problems of national and international importance
Rockefeller Foundation	Agricultural Science and Nutrition, Reproductive Biology, Demography, Tropical Medicine	Awards fellowships in support of its programmes and cooperative projects in USA and abroad
Carnegie Corporation	Special attention to educational projects	Approximately 7.5% of the income may be used in certain countries which are members of the Commonwealth. Current geographical emphasis are Southern Africa, the Caribbean and, to lesser extent, the South Pacific. Limited support for experiments, meetings, travel and publication.
Toyota Foundation	Human and Natural Environment, Social Welfare, Education and Culture and other fields	Through its International Division, support is aimed at developing countries for projects that best meet the needs of their present day society. Recently the Programme has been focussing on projects in South-East Asia
Alexander Von Humboldt-Stiftung	All disciplines to foreign scholars who work at universities or other research institutes with demonstrated ability in independent scientific research	Awards post-doctoral fellowships for research in West Germany (age not over 40). Guided by the belief that "scientific progress depends upon international cooperation based solely on scientific criteria".

Appendix A
Typical Administrative and Support Staff Costs for Various Activities Enhancing Programme Development and Management, and Institution-Building

	UK £
• Independent Regional or International Centre for Science, (recurrent costs of staff and administration; one year)	670,000
• Project Director (three years; including travel and logistics)	120,000
• Project Planning Workshop (including travel; 25 participants; one week)	40,000
• Project Review Workshop (including travel; 30 participants; one week)	45,000
• Workshops (one week; excluding travel)	17,000
• Research assistant/scholar, (one year)	12,000
• Travelling Scholar/Fellow (four months; for Project Director to transfer results to decision-makers)	10,000
• Publication of project results (edited by Project Director)	15,000
• Two-day Regional Seminar for public awareness of scientific and development trends (50 participants; part support for travel)	15,000
• Visiting Professor (one year; including travel and logistics)	40,000

(Based on the International Federation of Institutes for Advanced Studies estimates)

ENERGY SYSTEMS FOR COMMONWEALTH COUNTRIES

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1. INTRODUCTION

Commonwealth umbrella covers over 45 independent nations, exhibiting a vast diversity in area, population density, culture, language, level of development and industrialisation, extending from nations with a population of a few thousands to a nation like India whose population of 670 million exceeds the combined population of all the other commonwealth nations. Per capita income of these nations range from less than 200 dollars per annum to over 11,000 dollars per annum. The total number of nations and their diversity represent a statistically significant proportion of the world and hence it is not surprising to see a linear correlation between the per capita GNP and per capita energy consumption (Fig. 1). The pattern of energy consumption among commonwealth nations varies between about 0.1 ton coal equivalent to almost 12 tons coal equivalent, practically in the same ratio as their per capita GNP.

Per capita energy consumption is a true index of the industrial progress achieved by a country. Over 30 countries in the commonwealth, whose total population accounts for more than 85% of the commonwealth, have a annual per capita income of less than $ 1,000 and per capita energy consumption of 0.1 - 0.5 ton coal equivalent. Of the total energy of about 1 billion mtce consumed by all the commonwealth, two thirds is accounted

for by just three countries namely Australia, Canada and United Kingdom whose combined population is less than 10% of the commonwealth population.

A close examination of the socio-economic conditions of the commonwealth countries indicates that practically for all countries, whose per capita income and per capita energy consumption are low, the industrial output contributes very little to their Gross National Product and the volume of manufacturing industries in such countries is negligible (see Fig. 2). Most of these countries are agriculture based. Yet even their agro based industries are not adequately developed. Their export primarily consist of agricultural or ocean produce and raw materials including minerals. Most of these countries import finished products at a high cost and practically all of them import machinery, transport equipment and fuel including petroleum products.

2. STATISTICAL APPROACH

Irrespective of the region to which these countries belong, they essentially can be classified under two primary categories - large countries having large population such as India, Bangladesh, Nigeria, Uganda, Kenya and Tanzania and the rest of the smaller countries with lower population. Notwithstanding, a characteristic of all these countries is that most of them do not possess conventional energy resources such as fossil fuel, coal, oil, gas and hydro in adequate

quantities. Most of the smaller countries, in fact, do not have any of these resources and even larger countries like India have limited resources.

Assuming that the minimum goal for increased per capita energy consumption by the year 2000 should be at least 2 mtce, total energy requirements for these countries is listed in Table 1. A close look at the energy consumption pattern prevailing at present indicates that the bulk of the per capita energy consumed is in the form of hard fuels and only about 10-20% of the consumed energy is in more convenient forms like electricity. Whereas such a pattern is understandable when the per capita energy consumption is low, improvement of quality of life in general and enhancement of the gross national product which demand higher level of industrialisation, necessarily require enhancement of energy consumption in the form of electricity. Assuming, on a conservative basis, that at least 50% of the required increase in energy consumption has to be in the form of easily usable power like electricity, installed capacity required for electric power by the year 2000, for each of the countries is also listed in Table 1. In the case of many countries, the total installed electricity capacity has to increase by as much as a factor of ten or more if this dream is to be realised.

3. ENERGY SOURCES

Theoretical options available for energy sources are very large, ranging from renewable energy sources to depleting

sources and from conventional types using coal and gas to nuclear and solar energy systems. It is more practical to consider the energy options under commercial and noncommercial types. Irrespective of categorisation, overall development of any country whose per capita energy consumption and gross national product is low demands a decentralised energy system involving a judicious mix of technologies and types of energy resources. Small scale decentralised systems, particularly involving low technology are the only practical means of improving the quality of life in vast rural areas. On the other hand large scale centralised systems are imperative for providing power to industrial sectors.

In the high technology area, energy harnessed from sources such as geothermal, tidal, ocean temperature gradients and from waves and ocean currents either have localised potential or their technology is not sufficiently developed to make them an economically viable alternative. Nuclear power systems, can augment the energy requirements of large countries but both because of the capital costs and non-availability of adequate technical manpower base, nuclear alternative has little significance to the vast majority of small countries. Less exotic photovoltaic conversion methods are economically unviable except over limited not easily accessible regions. More exotic satellite based solar power system is ruled out as a viable means of development for the countries under consideration. This leaves the use of fossil

fuels and hydroelectric power as the primary commercial power sources and large scale use of terrestrial based solar power as a possible viable alternative. The latter is particularly attractive from the point of view of most of the commonwealth countries. In selected areas such as coastal areas or small islands, wind power can also be effectively used, not on a commercial scale, but as a rural oriented energy source on a limited scale.

Low technology options such as the use of renewable resources essentially can be effective in augmenting non-commercial forms of energy which can, in particular, assist in improving the quality of life in vast rural areas for limited purposes such as irrigation, agriculture, pumping water, cooking and light. Of the approximately 100 TW yr/yr of fuel equivalent biomass produced from solar energy, about 23% is fixed in Swamps, Grasslands and Tundras, 28% in forests and 10-12% in cultivated land, accounting for a total of about 62% or 62 TW yr/yr. The rest are fixed as ocean algae. We can assume that about 40% of this total (i.e. 25 TW yr/yr) is available for harvesting without seriously affecting ecology of the biosphere. Accounting for the basic requirements of population for providing food, lumber and associated production in cultivated land and less than 50% efficiency due to inefficient collection and conversion of wood to charcoal or sugar to cellulose, a maximum of 6 TW yr/yr potential is available from renewable energy sources which,

in principle, is equivalent to 1 mtce per capita for the world population. Unfortunately, the renewable energy source is not amenable for commercial use because of its low quality. Notwithstanding, for use in vast rural areas, renewable energy resources do provide an attractive alternative.

4. PROMISING AREAS OF DEVELOPMENT OF RELEVANCE TO COMMONWEALTH COUNTRIES

We examine the promising areas of development with particular reference to commonwealth countries and the possible technology development programmes which can be mounted under each category. No attempt is made here to programmatically discuss the possibility of initiating programmes for the discovery of new resources either fossil fuel, gas, oil or other resources.

COMMERCIAL ENERGY SYSTEMS

(i) Utilisation of fossil fuel

With the available coal resources of over 10,000 billion mtce (10,000 TW yr), continuation of coal as a major energy source is inevitable. Considerable potential exists for finding coal deposits in Africa and South East Asia, in particular. For a small country, discovery of coal resources of even 20-50 million ton can make a substantial difference in its energy potential. Both in terms of mining and in the use of low grade coals with energy content of 1500 kilo cal/kg (which is just about one fifth of the energy obtained from

good coal), large R & D efforts are required for efficient use of this resource. A number of methods for coal gassification and liquification are now available for producing liquid fuels and at the same time conserving the gas generated. The problem is adoption of such methods in less developed countries and introduction of these technologies. Effective use of low grade coal for energy production will be an important breakthrough. The possibility of using even the ash content for cement production also requires to be studied carefully for more optimal utilization low grade coal.

Even more important is to note that in most of the developing countries, which is true of commonwealth, the thermal stations are run at very low efficiency level partly due to lack of trained manpower and partly due to the use of obsolete systems. Improvement of efficiency of thermal installations, reduction of transmission losses are two vital areas where assistance to developing countries would be of immense help.

(ii) Solar Power

Solar thermal electric conversion (STEC), in spite of the technological problem, is a viable candidate of production of commercial power - concentration of solar energy to produce temperatures of about 600^{o} C using suntracking mirrors (Heliostats) and focussing of solar energy on a boiler located atop a 100-250 meter tall tower to produce superheated steam which can then be used, through even conventional steam cycles, to generate electricity is a proven concept.

In spite of the low efficiency realised in the direct conversion of solar energy and the present high cost of production, new developments of low cost materials and improvement of thermo-mechanical systems could make this process particularly attractive to most of the commonwealth countries. One important factor that dictates effective utilization of solar energy on a large scale is efficient and economical storage of energy. Intensive R & D is required to evolve low cost methods for efficient storage. Development of modest low cost 5 MW STEC modular type or unit is a single important project which could be of immense help in solving the energy problem.

NONCOMMERCIAL SOURCES

(i) Biotechnology

Conversion of biomass into energy is undoubtedly the best soft energy option for use in localised rural systems. Biomass is by far the highest quality form of indirect solar energy with a potential release of oxidation energy (by combustion) of 16 million Btu/ton, about 60% that of high grade coal. Further, because biomass energy can be released at flame temperatures of several thousand degrees centigrade, its theoretical carnot and practical efficiencies are high. Additionally, even though at low efficiency, practical methods of biowaste conversion to gas are already available and are being used in rural areas in some countries. It is possible to increase the efficiency of bioconversion with the help

genetic engineering techniques such as the use of Rhizobium bacteria for the degeneration of Soyabean plants. Studies are required not only in the optimal design of bioenergy plants and in conversion of biomass but also in ensuring ecological balance particularly when large scale use of forests are made for feeding the bioenergy plants. Where biowastes such as gobar gas is used, characterisation of efficiency as a function of pressure and temperature and optimal design and operation of plants with low cost, locally available material requires to be extensively studied. Introduction of fast growing monocultures to improve biomass yields and to achieve true "cultivation" needs to be studied if energy crops have to be evaluated from the point of view of long term ecological risk. Nonetheless, use of renewable bioresources for small scale energy production in rural areas is a highly promising energy resource for developing countries.

ii) Low Cost Wind Power Systems

The use of wind energy available upto heights of 200 meters above ground level where wind fields are favourable such as in coastal areas is yet another energy resource which can be usefully exploited. Wind power, unlike biomass, generates high quality energy which can be used to produce either electricity or stored mechanical energy. The main problem is the uneven distribution of wind power and the problems associated with energy storage. Even though the

theoretical potential of wind power is large, practical considerations such as choice of locale, cost of storage, environmental considerations etc. impose restrictions on the use of wind energy. Nonetheless, wind energy for pumping water for irrigation in rural areas could be very economically accomplished if the cost of wind mills could be brought down with appropriate design and choice of materials.

5 ACTIONS TO BE INITIATED

All the major projects identified above are of immediate relevance to the commonwealth countries and hence need to be initiated on a high priority basis. Some of these projects are already being pursued in various commonwealth countries. Information gathering and dissemination of the outcome of such projects is the first step to be taken. Establishment of a commonwealth science and technology centre for information gathering, dissemination and providing active technical assistance and training in relevant areas could be a possible long term solution. In the interim, however, these activities have to be carried out by the commonwealth office.

Funds may have to be provided for sharply tuning the programmes, with the end result in view, even after identification of the groups who are already engaged with these technological problem. The same groups can also be requested to provide in house training for personnel from

other commonwealth countries. Most of the large commonwealth countries have built research organisations with adequate technical manpower and hence need essentially assistance, both in terms of training for specific problems and in terms of finance to mount meaningful programmes in the area of energy resources. In the case of smaller commonwealth countries, it may be viable to promote regional centres of excellence from which cooperatively the smaller countries could draw upon.

The following actions are suggested :

1) Identification of expert R & D groups in commonwealth in each of the areas suggested earlier, to act as focal points for putting intensive efforts and carry out end to end experiments. It may be necessary to fund these agencies to enable them to come up with the design of a proto-type end product which can then be used on a large scale.

2) Same agencies could also be used for training manpower for other commonwealth countries.

3) Once the technology is developed, transfer the technology to those countries whose needs and infrastructure justify large scale manufacture of items such as biogas plants, windmills etc.

4) Setting up of a commonwealth science and technology centre, with a small group of experts in different application areas of relevance to all commonwealth countries should be

seriously considered. Such a centre should not only be able to act as a clearing house for information dissemination but also act as a catalyst in solving the problem of relevance through identification of expert groups within or outside the family of commonwealth, commissioning such groups to carry out R & D after sharply defining the problems and then monitor their progress to ensure fructification of these programmes. The centre in fact will act as a liaison group between the end user and the expert R & D group. Occasionally, the centre personnel themselves may take up some problems of relevance.

Table-1

Present energy consumption and required installed electricity capacity in the year 2000 AD to meet a 50% of minimal 2.0 mtce per capita energy consumption goal for various Commonwealth countries.

No.	Country	Population in millions	Per capita energy consumption mtce	Projected population in 2000 AD in millions	Additional energy requirement to meet 2.0 per capita mtce mtcex10^6	Required installed electricity capacity in Mega Watts for 50% additional energy
1	Antigua	.10	1.35	.2	.3	300
2	Bangla Desh	90.0	.04	140.0	250.0	$250x10^3$
3	Barbados	.25	1.1	.3	.4	400
4	Belize	.15	.7	.2	.3	300
5	Botswana	.8	.4	1.6	2.8	2800
6	Cyprus	.6	1.7	.8	.6	600
7	Dominica	.08	.2	.1	.2	200
8	Fiji	.6	.5	.9	1.5	1500
9	Gambia	.6	.1	1.0	1.9	1900
10	Ghana	11.7	.3	20.0	35.0	$35x10^3$
11	Grenada	.1	.2	.2	.4	400
12	Guyana	.8	1.2	1.2	1.4	1400
13	India	670.0	.2	990.0	1800.0	$1800x10^3$
14	Jamica	2.2	1.3	3.3	3.8	3800
15	Kenya	17.0	.2	32.0	60.0	$60x10^3$
16	Kiribati	.06	.3	.1	.2	200
17	Malawi	6.2	.07	10.0	20.0	$20x10^3$
18	Malayasia	13.4	.7	20.8	30.0	$30x10^3$
19	Malta	.3	1.2	.4	.5	500
20	Mauritius	1.0	.4	1.3	2.2	2200
21	Nigeria	85.0	.1	150.0	280.0	$280x10^3$
22	New Guinea	3.0	.3	4.5	8.0	8000
23	St. Lucia	.1	.4	.15	.3	300
24	St. Vincent	.1	.2	.15	.3	300
25	Seychelles	.06	.6	.1	.2	200
26	Sierra Leone	3.5	.1	6.2	12.0	$12x10^3$
27	Solomon Is	.2	.2	.4	.7	700
28	Sri Lanka	14.8	.15	21.0	40.0	$40x10^3$

Table 1 (continued)

No.	Country	Population in millions	Per capita energy consumption mtce	Projected population in 2000 AD in millions	Additional energy requirement to meet 2.0 per capita mtce mtcex10^6	Required installed electricity capacity in Mega Watts for 50% additional energy
29	Swaziland	.6	.3	1.1	2.0	2000
30	Tanzania	19.1	.05	35.0	68.0	$68x10^3$
31	Tonga	.1	.2	.2	.3	300
32	Uganda	13.2	.04	22.0	40.0	$40x10^3$
33	Vanuata	.1	.5	.2	.3	300
34	W.Samoa	.16	.3	.2	.3	300
35	Zambia	5.8	.8	11.5	18.0	$18x10^3$
36	Zimbabwe	7.4	.8	17.4	28.0	$28x10^3$

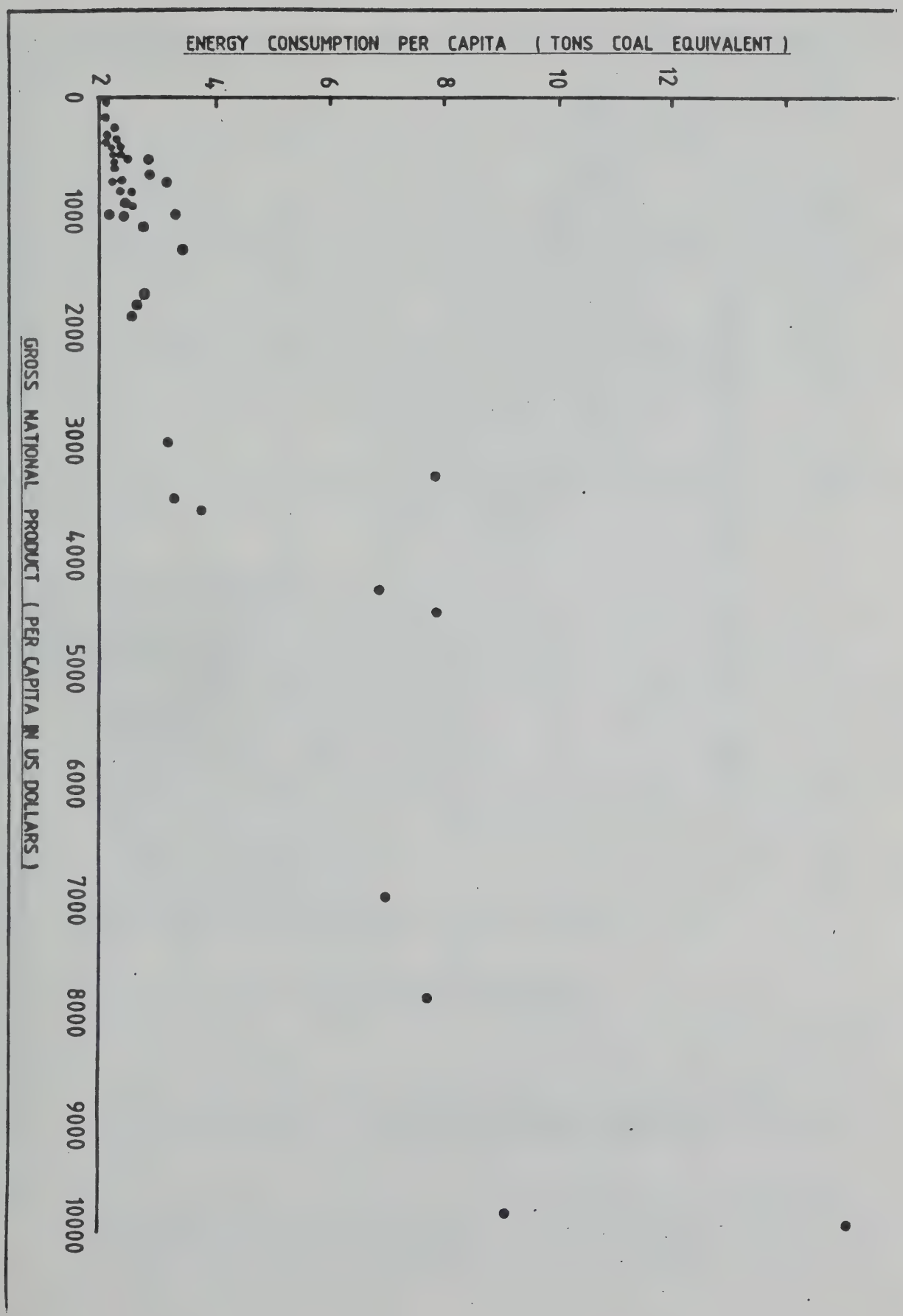
ENERGY CONSUMPTION PER CAPITA (TONS COAL EQUIVALENT)
2
4
6
8
10
12
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
GROSS NATIONAL PRODUCT (PER CAPITA IN US DOLLARS)

Fig. 1

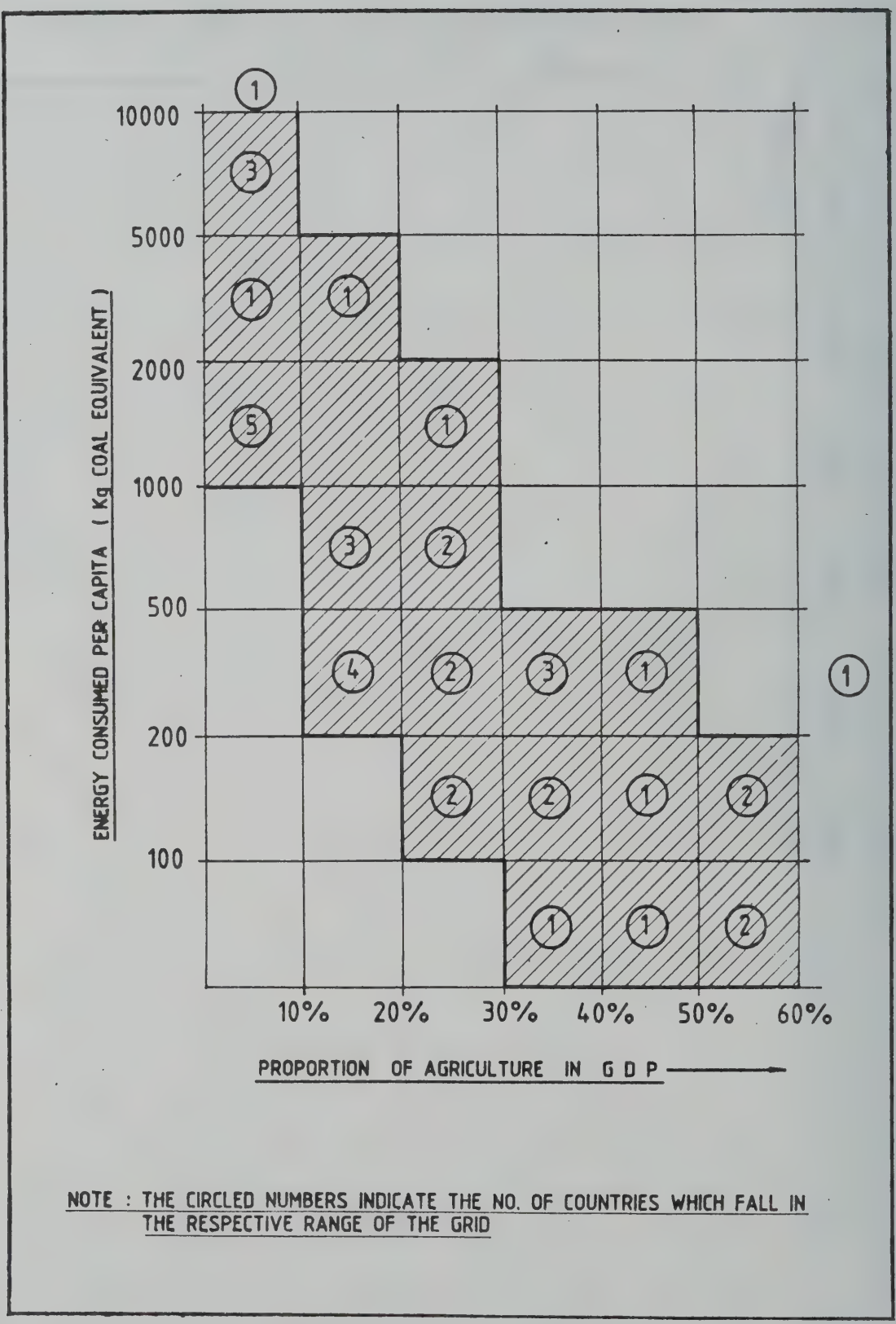
ENERGY CONSUMED PER CAPITA (Kg COAL EQUIVALENT)
10000
5000
2000
1000
500
200
100
10%
20%
30%
40%
50%
60%
PROPORTION OF AGRICULTURE IN G D P
NOTE : THE CIRCLED NUMBERS INDICATE THE NO. OF COUNTRIES WHICH FALL IN THE RESPECTIVE RANGE OF THE GRID

Fig. 2

Geosciences General

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1. Introduction

With the shift in programme emphasis to the application of science to technology relevant to development, it is considered that geological research should focus on those subjects that serve to increase the basic knowledge of the mineral potential of the less-developed Commonwealth countries. Subsequent mineral exploitation increases the social and economic development of both low and middle-income countries through the domestic production of local raw materials, import substitution and the export of domestic surpluses. At the same time, relevant technologies and methods developed in the industrialised countries could be tested and, perhaps, adapted in diverse environmental conditions.

Three main foci within the geosciences are thought to be suitable for inclusion in the expanded programme of scientific cooperation: applied geochemistry, applied geophysics and remote sensing. Information technology is a related subsidiary topic.

2. Applied Geochemistry

The application of geochemical exploration techniques, that have been developed in the more industrialised countries of the Commonwealth, to the less developed Commonwealth countries where there are different climatic, economic and scientific conditions, is crucially important if the mineral resources of these countries are to be fully exploited. The time-frames and appropriate modalities obviously depend upon the human and financial resources of the receiving countries. Transfer of information and training of skilled manpower would be the main aims in the less developed countries while in countries where research institutes already exist, joint research projects would be directed towards the adaptation of technology developed in countries such as Australia, Britain and Canada to the local conditions. Within the general area of applied geochemistry the following specific subjects may be amenable and relevant to the proposed expanded programme of scientific cooperation:

2.1 Rock Geochemistry in Mineral Exploration

Three-dimensional geochemical surveys based on primary halos and primary and secondary leakage halos have received relatively little attention to date. Such surveys offer the potential to locate deeply buried ore deposits and also to assess their composition and size. By utilising analyses of surface rock samples, underground samples for mines, and drill cores it is possible to define the type and distribution of enveloping and leakage halos associated with mineral deposits.

Long-term collaborative research could be carried out between research institutes in Australia, Britain and Canada linked to research institutes in countries such as India, Zambia, Zimbabwe, Botswana, Nigeria and Malaysia, where mineral resource development currently contributes

substantially to the GDP. The potential benefits would be the development of new concepts that could be applied to mineral exploration. The development of such new concepts and exploration methodology are extremely important as established exploration methods such as stream sediment surveys have been used extensively in most of the above-mentioned countries and it is now necessary to investigate new techniques.

2.2 Investigations into the Supergene Processes that Control the Dissolution, Transport, and Redeposition of Ore-related Elements

Exploration geochemistry is largely an empirical science but if concealed ore deposits are to be found, then much fundamental work needs to be carried out in order to provide a scientific basis for the advancement of appropriate technology. Detailed research is required into the overburden of oxidised residium over sulphide ore deposits; mechanisms of solution, transport and reconcentration of mobile elements; conditions controlling supergene mineral phases; physical properties of those phases that will allow abundant accumulation of specific sizes of particles in a secondary dispersion train; and sedimentological controls that govern the location of accumulations of mineral grains producing geochemical anomalies. Partial solution or sequential dissolution techniques and their application to the search for deeply buried ore deposits also need further investigations. Collaborative research between established research institutes in many different Commonwealth countries would form the basis of this particular programme. Again, existence of an extremely wide range of geological, topographical and climatic conditions in the different Commonwealth countries would greatly facilitate the advancement of the programme. The transfer of information and the training of skilled manpower would also be involved as the programme developed.

2.3 Regional Geochemistry

The results of regional geochemical surveys, usually presented in the form of a geochemical atlas, are of great value to government, industry, planners and scientists as they provide a fundamental basis for studies in mineral exploration, agriculture, land use, pollution monitoring, veterinary science, epidemiology and geological studies of the deep crust. Geochemical sampling, analytical, and interpretative methods, aimed at providing systematic information on the concentration of chemical elements over large areas, have been developed in Australia, Britain and Canada. Regional geochemical studies have been used as an aid to mineral exploration in many African Commonwealth countries, including Botswana, Sierra Leone, Uganda and Zambia. The use of regional geochemical data could be expanded to encompass the monitoring of environmental pollution and to aid the integrated management of natural resources. Many countries in the Commonwealth do not have regional geochemical survey data available, so cooperative programmes between research institutes in countries such as Australia, Britain and Canada and government institutes in countries needing regional geochemical data could be carried out as short-term projects based on training and information exchange. The main aim would be to train geochemists in the receiving countries so that they could carry out regional geochemical surveys and utilise the results for mineral exploration, pollution control, epidemiology etc.

2.4 Offshore Geochemistry

Offshore geochemical studies are relevant to sea-bed mining, management of maritime zone and environmental pollution. The UK continental shelf has been studied by instrumental measurements taken *in situ* on the sea-floor and by laboratory analysis of sea-bed samples. The development of instrumentation and sampling techniques for offshore geochemical research and the application of the results to mineral exploration in the marine environment require further investigation.

Long-term programmes of scientific cooperation between Commonwealth countries having the financial resources to support geochemical studies of the maritime zone would provide a sound scientific basis for its future economic development. Without fundamental geochemical information it is impossible to carry out maritime mineral exploration or monitor pollution.

2.5 Groundwater Geochemistry

Groundwater samples provide a useful medium for analyses in both geochemical mineral exploration studies and studies of pollution of groundwater by industrial effluents and waste of various kinds. Studies of groundwater geochemistry will become increasingly important and may be of special relevance to the disposal of radioactive waste in the more industrialised Commonwealth countries. Groundwaters have deep penetrative power in many geologic situations and these sampling media should be more extensively used for mineral exploration, especially in areas of high mineral potential.

2.6 Application of Geochemistry to Petroleum and Gas Exploration

Research into the use of geochemical methods in the search for hydrocarbons would be a suitable field of scientific cooperation between such Commonwealth countries as Britain, Canada, Nigeria and India. This would involve long-term collaboration of both governmental and private research institutes.

2.7 Other Areas of Research in Applied Geochemistry

Refinement of the techniques of biogeochemical and geobotanical mineral exploration would lead to an increase in their importance. These techniques are not particularly widely employed in mineral exploration projects but would become more important in the future.

Research into the use of gases as indicators for deeply buried ore deposits could be carried out by Commonwealth research organisations. The wide variety of geologic and climatic environments found within the Commonwealth would permit very effective studies to be carried out.

3. Applied Geophyscis

Possibilities for scientific cooperation in applied geophyscis can be divided into two main groups:

1. Applications of existing techniques to new problems/areas

2. The development and wider use of interpretive methods.

3.1 Applications of Existing Geophysical Techniques to New Problems/Areas

These applications can be specific to certain areas (eg the airborne geophysical survey of Botswana) or to certain minerals (eg finding geophysical methods useful for kimberlite (diamond) exploration), or both (eg structural studies of tin-bearing granites in Malaysia). There is wide scope for cooperative ventures here, many of which have already been carried out under the auspices of organisations such as CIDA or ODA.

Geophysical techniques for the direct detection of mineralisation (usually electrical, electromagnetic and magnetic methods, sometimes including gravity) are normally used in conjunction with other techniques (geochemistry etc) in integrated detailed surveys of relatively small areas. Indirect approaches, involving the characterisation and detection of likely host rocks and their structural settings often precede such surveys and sometimes replace them (eg in oil and gas exploration): they may cover large areas and are generally more suitable as cooperative projects. The main geophysical techniques used in such regional structural investigations are airborne surveys (especially magnetic and radiometric measurements), gravity, and seismic surveys (both marine and on land), the last being the main tool for oil and gas exploration. In some circumstances these represent the only, or principal means of investigating structure prior to drilling, eg at sea or in sand-covered deserts.

Most Commonwealth countries now have some form of regional gravity coverage, Malaysia being a notable exception. This represents a relatively inexpensive and rapid means of obtaining information on deep structure. Many countries have complete coverage by airborne magnetic surveys and nearly all have a partial coverage. Seismic surveys, being expensive, are almost entirely confined to prospective oil areas and have usually been carried out by commercial oil organisations. These surveys are designed to investigate, specifically, potential oil-bearing structures in sedimentary basins rather than the basement beneath, or the structure of a region as a whole.

Although there is scope for collaborative projects in all of the topics mentioned above, there is one which is particularly suitable for consideration. It is increasingly recognised that long, seismic-reflection profiles to investigate basement structure can provide a large amount of information which is not available in any other way, and which provides a better understanding not only of the basement, but of overlying structures in the sediments. This has been frequently demonstrated in countries which have recently set up programmes to measure such profiles, eg USA (CCORPS), Britain (BIRPS) and Canada (COCRUST). The cost can be kept down by a degree of collaboration with commercial operators. Although the dissemination of results has been excellent, most of these programmes have so far been restricted to the immediate vicinity of the country concerned. There seems to be great scope for international collaboration here.

Deep crustal seismic-reflection profiling can provide useful scientific information in the short-term (2-4 years) but there is also scope for long-term programmes. Collaborative research, with a training element, is indicated and the potential benefits to a developing country include a better understanding of the geological structure (and hence the mineral

potential) and an increase in skilled scientific manpower. The infrastructure required would be research institutes and geological surveys with similar interests and there seems to be scope for such work, for example, in Malaysia, Zimbabwe, Kenya, and Tanzania.

3.2 The Development and Wider use of Interpretive Geophysical Methods

A large number of organisations not necessarily employing qualified geophysicists, make some geophysical measurements, but due to lack of expertise, or of access to a computer, or of suitable programs to run, do not obtain as much information from these measurements as they could. In other organisations which do have these facilities, the programs used are often not transferable to another type of computer, or are proprietory and confidential, and so not generally available. There is a need for freely available geophysical interpretation programs which are easy to use, well documented and operate on low-cost mini or micro-computers. CSIRO's Division of Mineral Physics in Australia already runs a scheme in which software of this kind is made available to other organisations on payment of a fee, and it may be feasible to expand this scheme, or copy it, as a collaborative project amongst other Commonwealth countries.

Short-term benefits could be obtained by the development of easily applied computer software for use on low-cost (mini/micro) computers to interpret geophysical data but, if successful, projects should be on a continuing basis. Information exchange and collaborative research with developing countries are indicated.

Participating countries, particularly those without well-established geophysics departments, could benefit by adopting and, if necessary, adapting the technology. They would gain the ability to apply more sophisticated, quantitative, geophysical interpretation techniques using relatively cheap hardware - hitherto possibly only available on larger, mainframe computers. The organisations providing the software would need experienced geophsical programmes with appropriate computing facilities. Cooperation between Australia, Britain, Canada and India on the one hand, and the African Commonwealth and Malaysia on the other is envisaged.

4. Remote Sensing

Historically, remote sensing techniques have been based on aerial photography. However, the development in the early 1970s of sensors such as the multispectral scanner (MSS) and imaging radar, able to record wavelengths in the electromagnetic spectrum beyond the visible, and the potential for processing and enhancing this data digitally, has led to a rapid expansion in the use of remote sensing in the geosciences. Satellite imagery offers the advantage of providing a synoptic view of large areas of the earth's surface and is therefore particularly suited to regional investigations. Research and development are on-going and further technological improvements are to be expected, but there already exists a well-tested base for applications in resource assessment, and there would seem to be considerable scope for further extending the use of these techniques to low/middle income developing countries as inputs to mineral resource programmes.

Topics of particular importance are as follows:

4.1 Geological Mapping

The provision of reliable geological maps at both regional and detailed scales remains an essential pre-requisite for mineral exploration and resource development. Photogeology will continue to be a fundamental mapping tool but MSS imagery and radar can provide important inputs, especially in regard to structure, in the preparation of both new and revised maps.

4.2 Mineral Exploration

Landsat MSS imagery has been successfully used to detect mineralisation including uranium, nickel laterite and porphyry copper deposits. Detection of heavy metal deposits relies much on the spectral response of limonitic minerals in gossans. However, Thematic Mapper (TM) data from the latest generation of Landsat satellites, with increased spectral range and resolution, offers the potential for discriminating hydros, hydro-thermal alteration minerals such as kaolinite, sericite and alunite. Other possible approaches to both mineral and petroleum exploration include the use of Landsat and radar (eg SIR) for structural analysis, and TM data for geobotanical studies.

4.3 Other Applications

These include coastal and shallow marine surveys, geothermal energy surveys and the study of geological hazards (engineering geology).

Inputs from remote sensing will be to larger projects and will in general be short term. However, a long-term build-up of expertise and possible technology in some developing countries can be anticipated.

Implementation of projects should be through collaborative research but it can be anticipated that there will often be the need for preliminary specialist training of the local scientist at an overseas remote sensing, image processing facility.

Potential benefits will vary from country to country. Landsat MSS imagery, for example, has been found to have most application in arid or semi-arid terrain and would consequently be particularly useful in parts of Africa* whereas imaging radar has the capability to penetrate cloud and can provide structural detail over densely-vegetated tropical regions+. Specific benefits would relate to the particular resource development or mapping project. In the longer term, training would result in local scientists able independently to continue applied research in remote sensing according to future country needs. The installation of image-processing computing facilities in overseas research establishments might be a less essential requirement in the short-term except where on-going programmes involving a remote sensing input could be anticipated. For those industrialised Commonwealth countries providing expertise (eg Canada, Britain, Australia, benefits would include the testing and adaptation of technology over a more diverse user market.

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* eg, Kenya, Botswana, Zambia

\+ eg, Guyana, Papua New Guinea, Ghana, Solomon Islands

Fundamental to the types of collaboration outlined would be the existence in the receiving country of a Government or University centre carrying out geological studies and the identification of suitable resource development projects. Infrastructural capacity need be minimal and might only involve a single qualified scientist.

5. Information Technology

Governments of both mining and consumer countries require access to information on, and analyses of, world and local trends in resource identification, resource quality, and production and consumption of mineral materials. These, and related, factors have deep implications for the local economy, relationships with other countries, defence strategy and national and international environmental issues.

The provision of accurate information and informed advice on mineral resources and related subjects is often provided "in-house" by the research branches of appropriate Departments of Government, but in some countries the relevant expertise is maintained within Bureaux of Mines or similar agencies which are also engaged on research and advisory work in a multiplicity of associated fields.

Although most developing Commonwealth countries with significant mining industries have Mines Departments and Geological Surveys, it is clear that few maintain within them, personnel who are capable of becoming involved in short-term policy making and in economic/political strategy covering the field of mineral resources, production and trade. Because of the need for expertise which is multi-disciplinary in character, and because demarcation which tend to exist between disciplines are often exaggerated in those parts of the world where public services and industry are less advanced, the necessary facilities may not be available to decision makers. Moreover, while Government Departments in industrialised countries can depend upon indigenous industry for the great range of information and advice, that source is not open to administrators in developing countries who, by necessity, lean heavily on such knowledge as may be available within their less knowledgeable scientific institutions.

The development of multi-disciplinary expertise in the fields of mineral resources, mining, minerals trade, mineral and mining law, market mechanisms and end use would be of great value to many Commonwealth countries and could be integrated with associated activities such as technical assessment of indigenous mineral resources and the work of existing mining record offices where these have been established. Even in countries with no mining industry, questions affecting imports of raw materials and the conduct of local quarrying can be greatly influenced for the better by access to accurate information and sound advice.

There may be scope for some developing countries of the Commonwealth to benefit by promoting understanding of world mineral resources, production, trade and use within their public services. This would tend to enhance the value of indigenous production, lower the chances of unremunerative development, eliminate unrealistic policies on trade, and provide the data necessary to optimize the value of discussions bearing on future relationships with other countries.

Geosciences: Earth Resources and Development

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Introduction

Of all the activities in the Geosciences that might give the greatest returns in stimulating developmental efforts within a country, the steps taken to ensure a detailed knowledge of its own natural resources are probably basic and should precede any other. The term natural resources must be construed broadly, and within the field of earth science, wholly or in part, it comprises non-renewable and renewable resources. The former include metallic ores, non-metallic minerals such as fertilizers and construction materials, and energy minerals, including uranium, petroleum products, and coal. Renewable resources, also within the field of earth science, include water, both sub-surface and surface, the soils, and the surface of the solid earth including that under the oceans. We must also include the gray area between renewable and non-renewable resources which includes many aquifers and some soils and sensitive surface terrains, which, when used or disturbed, are non-renewable on a human time scale, and, indeed, should be looked on as a wasting asset. In this paper, consideration of resources will be limited to those that occur within the earth, and will end upwards at the boundary between soils and living plants. The unity between all resources used by man, however, must be stressed, and they occur in the geosphere, the biosphere, and the troposphere. All of these remarks are, essentially, directed to activities with a long time frame.

I acknowledge the assistance and advice of colleagues within the Geological Survey of Canada, particularly R.G. Blackadar, A.G. Darnley, D.C. Findlay, G.A. Gross, B.E. Manistre, and R.A. Price. The views expressed, however, are my own.

Priorities and Economic Modelling

There is a strong tendency, when discussing the scientific priorities of a country, to concentrate on the high profile sciences whose applications through technology are so rapidly changing aspects of life in the so-called developed regions of the world, while ignoring the perhaps more difficult if less glamorous techniques of ensuring the existence of a knowledge base that will allow a planned use of local resources in balance with the human environment in less developed regions. In many parts of the world, by far the most important problems facing local populations involve such matters as water supply, physical and geochemical soil depletion, lack of raw materials, and uncertainty of energy supply. Such problems require for their solution sophisticated scientific knowledge, complex technologies, and above all, a cadre of professionally trained scientists capable of advising on resource potential and management.

There is an equally strong tendency to overlook the resources below our feet in current economic modelling. For instance, there is no mention of resources or resource exploitation in the Economic Data Summaries within the Commonwealth Fact Book, even though the size of the contribution made by minerals, in the broadest sense, in any country, may range from 0.6% to 20% of its GNP, and is between 8% and 12% for many. The developing situation of resource depletion today in some of the most developed countries, coupled with continuing global population growth, makes it imperative that less developed areas of the world should have a sound knowledge of their own resource endowment, and the technical capacity to ensure the maximum benefit from its development. The parallel need for environmental protection is equally pressing and this also requires an adequate knowledge base.

Such resource knowledge is necessarily site specific. While the earth sciences have developed many sophisticated techniques for resource detection, assessment and exploitation which are widely applicable, nevertheless, all natural resources within a country or indeed within any specified region, are unique to that region, and only limited extrapolation from other regions is possible. Such remarks apply to all resources, including biosphere, agriculture, forestry and soils, down into the geoscience base on which all rests.

In regard to minerals, including energy minerals and ground water, most easy deposits have been found. Some of the more sophisticated procedures needed for the next round of exploration and assessment are discussed below. It must also be realized that in any area of resource use, there must be a balance between development and environmental protection. Fortunately geoscience activities required for either are closely similar, and overlap broadly.

Limitations to Resource Development

Certain principles may be recognized in regard to activities concerned with resource discovery, assessment, and development. On the occasion of the 100th anniversary of the United States Geological Survey (1979) a one-week discussion, was held on the subject of "Resources For The Twenty-first Century". The proceedings were published in Professional Paper 1193 in 1983. Resource experts from many countries attended, and took part in formal papers and formal and informal discussions on the problems of developing resources including the need for mapping, describing and assessing the land, its energy and mineral resources, geological hazards, water, human habitation, and the geological factors affecting the environment. Certain important general principles were

established that are highly relevant to proposals in this paper concerning how the geosciences may contribute to developmental efforts during the next ten to twenty years. These are summarized briefly:

1. The most important inhibiting factor in resource development is lack of trained professional and technical personnel. Until such personnel are present in a country, full advantage cannot be taken of foreign expertise and advice, or technical assistance. Furthermore, it is vital that administrative and political decisions be taken based on in house knowledge and capacity.

2. There is a pressing need for surveys of all kinds which include mapping and inventory of the earth science base, including geology, geophysics, geochemistry, ground water, and evironmental studies including terrain sensitivity. Such surveys would have as an ultimate goal assessment of resource potential, and the knowledge base necessary for rational development and environmental protection.

3. A major block to rational resource development in many if not most nation states is the difficulty of influencing political and administrative arms of government to recognize that many technical resource decisions require a knowledge that may be lacking, and can only be acquired in a time frame longer than is normally considered in the political process. Here, again, the only way to overcome such obstacles is to build a competent cadre of professional and technical personnel.

4. The most important single mineral commodity in virtually every country in the world today is water, particularly the unseen potential of ground water. The study of this limiting factor to development is paramount. Frequently water resources are "used twice" in varieties of economic modelling.

5. Although resources appear abundant in terms of the geochemistry of the crust of the earth, technical, geographic and thermodynamic reasons suggest that the reality is disturbing. Resource endowment is grossly uneven, and energy requirements alone dictate a minimal ore grade for metallic minerals, just as geochemical considerations limit the usefulness of marginal soils. Limits to water are more direct and easily perceived.

Foci Amenable to an Expanded Program

It is difficult to formulate a logical list of subjects required by a national program and international co-operation within the earth sciences, because such activities are common to several or all of the desired applications. Indeed, the underlying argument of this paper is to emphasize that base studies in sciences concerned with the geosphere are an essential first step in the use of resources for the benefit of man, and that such studies serve equally the forces of development and exploitation as well as those concerned with conservation and the environment. The following suggestions seem applicable to most countries, although each area or region requires a different emphasis because of differing physical endowment and the stage reached in technological sophistication and training.

1. Known Resource Inventory

There are various models of differing complexity of use in assessing known resources. Manual or computer processable mineral data banks and accompanying maps may take many forms. A recent example is that of CANMINDEX (Canadian Mineral Deposits Index System). In countries with developed mineral resources, legislation should ensure adequate flow of processable information from the companies involved. Other examples might include Crop Land Inventory, Forest Resource Inventory and Inventories of Developed Surface and Ground Water. Such a program might be achieved, depending on the resource complexity and variety, in one to five years.

2. Resource Data Base

This is an activity designed to determine and identify or describe the environments in which resources, of all kinds, might be present but have not yet been fully identified. It is the main effort stage in any geoscience program. It necessarily overlaps all other activities and applications, and is the base from which most evolve. The activity should develop hierarchically from the fastest (coarse) data to a fine and detailed base which might continue indefinitely. This will vary according to the country, it's geography, geology, needs and environmental constraints. A suggested hierarchy (by D.C. Findlay) could include:

i) Landsat inventories and interpretations

ii) Aerial photography

iii) Topographic mapping (if required)

iv) Reconnaisance geological mapping (bedrock and surficial)

v) Airborne surveys including aeromagnetic, airborne electromagnetic and radiometric, gradiometer, and others

vi) Coastal (shelf) geophysical surveys and mapping

vii) Regional geochemical surveys if applicable and as indicated by previous surveys

viii) Detailed geological mapping, keyed to reconnaissance mapping probabilities

ix) Development of a data base management system using computer technologies

x) Site-tied geoscience projects of a great variety; e.g. local construction and industrial materials; mineral deposits studies; sedimentary basin investigation for fuels, water, minerals, and waste disposal; geothermal energy regimes; surficial deposits, e.g. bauxite, and surface evaporites. These might proceed to drilling stages.

An alternative plan (by A.G. Darnley) is shown on Table I.

There are obvious and continuing feedback loops between stages one and two. The selection of areas and resource targets must be made successively as surveys proceed. Many components of stage two, however, could proceed concurrently with stage one. There are important opportunities for technology development and transfer in nearly all components of stage two, e.g. airbourne surveying equipment and techniques, computer systems training and application. Airborne surveys, especially reconnaissance geochemical surveys, may yield more rapid preliminary results of wide application and employ fewer professionally trained staff in the field than ground geological data collecting. There can be no substitute, however, for eventual integration of all evidence in a type of unified model commonly referred to as a geological map. As soon as a base is established

TABLE I

GENERAL SEQUENCE OF EXPLORATION ACTIVITIES

Phase	Purpose	Air	Ground	Coverage and remarks
I	Preliminary geological analysis	Satellite imagery SLAR		To cover whole area
	Topographic map production	Air photography	Topographic ground control	To cover whole area; select critical areas for geological investigations
II	Reconnaissance Geophysics and Geochemistry	Aeromagnetic surveys Radiometric	Geological ground control Regional geochemistry	To cover whole area. To produce regional maps at 1:250 000; to eliminate ground from further investigation; to locate anomalous areas or gross features favouring the occurence of mineralization
III	Fill-in geology Geophysics Geochemistry	Aeromagnetic Radiometric Airborne Electromagnetic Gradiometer	Ground follow-up of geochemistry and geophysics; supportive geological investigations	Limited to (for example) 30% of area. To select zones meriting detailed ground investigation
IV	Detailed surface exploration	Helicopter-borne geophysics	All types of ground geophysics as applicable, i.e. electrical, seismic, etc. Soil and subsurface geochemistry. Pitting and trenching. Detailed geology	Limited to (for example) 5% of area. To find and examine mineralization; to locate drill targets.
V	Subsurface exploration	--	Drilling	Limited to (for example) 0.05% of area. To prove existence, grade and thickness of mineralization.

with adequate personnel to handle some of the data and interpret them for administration, then outside advice, cooperation and assistance can be used on an accelerating scale.

3. Resource Assessment and Analysis

By integrating stages one and two, it should be possible to identify target areas for various resources, and to construct a further hierarchy of developmental opportunities for the resources deemed the most likely. Here again, there are many models to choose from, and activities must be tailored to suit local conditions, stages of development and priorities. A design for a particular country or region would take into account the progress in stages one and two, and again there are feed-back loops. For a developing country, a type of model that might appeal would be the "folio" approach, i.e. stacks of geoscience data sets; examples might be cited from U.S.A., Canada, Australia, and the UK. The field of resource assessment and analysis is developing rapidly. Methodologies are appearing for many commodities, and allow probabilistic statements on resource size and frequency which are modified and refined as knowledge and data improve. Such analyses greatly enhance the desirability of a region for capital investment, both domestic and from abroad.

A corollary to these remarks, however, is that stage three demands access to a much higher level of cumulative professional expertise, experience and sophistication in resource matters than stage one or, at least partly, stage two. Here is scope for scientifically advanced Commonwealth Nations to provide knowledge transfer as opposed to technology transfer, and for the

country involved further to develop its own internal expertise providing it can demonstrate the importance of such activities to the political mind more accustomed to short term benefit.

4. Resource Development

This is largely beyond the earth science program framework. Selection of developmental opportunities and the implementation of incentive programs for exploration and subsequent development will depend on various mechanisms that follow logically from the information base generated by the previous stages. These, in turn, will be influenced by government philosophy, financing mechanisms, and other considerations. Nevertheless, a cadre of trained resource scientists and technologists is essential if the country is to reap the maximum benefit from its resources, both exploitive and environmental.

5. Natural Hazards

Although concern for safety arising from various terrestrial risks should be firmly integrated into the program outlined above, nevertheless, it is selected for a brief comment separate from other resource generalizations. This is a topic which is strongly site specific, but hazards of all kinds can be studied, understood and ameliorated. The common hazards include earthquakes, volcanic erruptions, landslides, floods, and unstable or sensitive terrain. Any country possessing one or more of these possible hazards might seek co-operative help, particularly from other areas of the world which suffer from similar possibilities.

Earthquake prediction still, for the most part, still eludes us, although huge benefits can be derived from wise site selection in building, and by judicious building codes. The difference in safety between correctly designed buildings and traditional construction, may be orders of magnitude. With volcanic erruptions, prediction is becoming more reliable, and there is usually time to put evacuation systems into effect. Each case, however, would require on site research and constant monitoring, and only general principles and rules might be brought from outside. Similarly, the slower acting problems of terrain sensitivity, which might range from permafrost to desert ablation, require specific understanding. Activities to ameliorate any of the above, however, must depend firmly on a reliable data base of the kind set out in stage two.

Recomendations

Most of this paper consists of comment on and recomendation for resource connected activities, but an attempt should be made to summarize some of the main conclusions.

1. Knowledge feeds on knowledge. Every country must provide an environment in which knowledge can grow. Aid, technology transfer, training and consulting from outside will all benefit a country in proportion to the desire within to establish expertise, and this requires administrative and political encouragement. The goal in any form of knowledge transfer across national boundaries should be to foster

collaborative research and its application. Exchange of concepts and experiences between Commonwealth members in similar resource circumstances could be most valuable in research planning.

2. A country should select earth science programs carefully oriented to particular situations and needs, in relation to facilities already established, scientific personnel available and the physical nature of the country, including its geology, geography, and land sensitivity. It should also be borne in mind that just as a good road may be used to carry many commodities, so a good earth science base may contribute to many desirable objectives. A reliable data base is the best means of encouraging investment capital in resources and of encouraging and controlling their development. Within the Commonwealth exchange of expert advice could lend credibility to resource assessments and thus stimulate flow of investment capital.

3. There are some major international earth science programs which are already of great value at little cost. These include the various systems of satellite imagery, various airborne remote sensing survey systems, and effective and sophisticated data handling systems available to those with a capacity to use them. Some of these programs are part of the highly successful International Geological Correlation Program, sponsored by UNESCO and the International Union of Geological Sciences. While generating relatively little support money, nevertheless, the projects within this program give access to a large body of expertise much of which is available at little cost. The value of IGCP is directly proportional to

capacity to make use of its projects. A side benefit of such international programs that is sometimes overlooked is that participation by scientists frequently ensures greater visibility for the importance of their work within their own country, and may lead to other possibilities.

4. The earth sciences logically lend themselves to regional groupings of programs. Bilateral or multilateral regional groupings, information exchange, mapping across state boundaries, and sharing of common facilities provide a means of increasing knowledge without necessarily increasing expenditures. Every attempt should be made to encourage such local or regional groupings which may be more logical than ambitious international projects.

5. The last word must be to reiterate the importance of training and education at every level as the first necessary step to any form of developmental program.

Need for Interaction in Geoscientific Activities among Commonwealth Countries

Director General
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1. Earth Resources form the backbone of agriculture and industrial production, and generation of large segment of national wealth. To have one's own resources is certainly an asset but that is not enough if these are not properly understood and fully utilised to generate the various wealth through adequate technology and investment. However, in the modern global economic order, not to have these resources is certainly a handicap but not necessarily a serious disadvantage if the nation has the technology and capital, as U. Thant said, "It is no longer resources that limit the decision, but it is decision that make the resources".

2. Coincidentally these two positions in the present economic order and development largely define the Developing and the Developed countries. Whereas the Developing nations with need for capital and technology to generate maximum wealth for their sizeable or fast growing population are alive to their resources, a large number of the Developed countries after attaining a high standard of living through easy access to earth resources, have now reached a stage of taking decision regarding resources for posterity.

3. Keeping in view the universal well-being and better living for the mankind everywhere, the vital question, therefore, is whether in the long range view the gap between the two situations could be narrowed down, if not bridged. Each country would obviously take its own view on this question. First by making the likely projections of its known and hypothetical resources, followed by identifying its own exclusive self interest as also the mutual or common interests.

4. The developing nations of the world support 67% of the world population but their percentage of development utilisation is only marginally significant: energy consumption 15%. industry 8%, science and technology 5%. The share of the major minerals during 1979 has been Bauxite 53%, Chromite 6%, Cobalt 16%, Copper 15%, Diamond 11%, Gold 5%, Iron ore 21%, Manganese ore 21%, Lead 20%, Molybdenum 11%, Nickle 30%, Platinum 3%, Potash 28%, Silver 19%, Tin 27%, Tungsten 5%, and Zinc 27%.

5. The Commonwealth countries' population of about 1 000 million accounts for 25% of the world's total population. Against this background out of 48 countries in the Commonwealth 29 countries fall under low and middle income level (less than 1 000 $ per year) where the GNP growth is very marginal. 13 Commonwealth countries have per capita GNP less than 125 $ per year and they fall under the most seriously affected Least Developed Countries.

6. Therefore, today's geosciences must provide solution to the whole range of problem from exploration to exploitation and beyond. The last few decades have shown an extraordinary diversification in the fields of activities concerning earth science. This development has been paralleled by an increase in sophisticated application. it is this new advance that must be transferred to the developing countries of the third in order to permit them to exploit their mineral resources for their own development. There is need for collaboration not only among geoscientists from the same nation but also amongst those from different countries. It is no longer sufficient to meet at conference but more frequent on-the-job contact by geoscientists from the developing countries and their counterpart from the developed countries is important for affecting transfer of technology. There is a major economic inter-dependence amongst all nations, both developed and developing, which is felt more today than in the past. The Commonwealth nations having long linkage with English language as the base will serve as the ideal forum for effecting inter-dependence and transfer of technology in the geo-scientific fields.

The Geological Survey of India (established in 1951) in its long developmental history, inherited, on the one hand the functions of a service department catering to the survey and resource needs of the country as per Government policies and on the other hand, it is a major institution concerned with the growth of fundamentals of geosciences, related research, development and technology. The two types of functions are amalgamated in a suitable organisational framework for pragmatic application of geoscientific activities in the country.

The basic nature and diversification of geosciences are such that besides the national interest served by geo-scientific Survey/Department progressive scientific links have to be maintained with other institutions and countries for updating and modernisation in chosen areas and disciplines. This philosophy for effective utilisation would be inter-departmental and interdependent interaction. This has necessitated to put emphasis on cooperative projects and programmes which are supported by the international geoscientific organisation, Commonwealth, etc. GSI like many other country organisations attaches much importance to such programmes.

Such oriented and fruitful participation and the required acceleration in international activities may be viewed in the background of the following broad framework of activities and needs.

7. In many spheres of geosciences the scientific needs transgress the territorial limits. As more and more new data and interpretations merge due to the progressive research techniques and developments in geosciences, new spots/areas, regions of the earth become the focus of worldwide attention thus providing the loci inevitably leading to international inter-dependence among the community of geoscientists on many aspects.

8. A few examples of world interests are outlined as under to illustrate this point.

a) Georesource Thematic (Prognostic) Maps

The meeting of the Heads of Geological Surveys has drawn attention to the value of geo-resources maps. The African Surveys have called for

standardisation of the scale for publication of maps and wide distribution of printed geological maps. The need for standardisation of map symbols and colours for legend has also been emphasised. Many geological surveys experienced the need for expeditious printing of maps and reports. In this connection they have called upon the Geological Surveys having expertise in the printing of maps and reports to attempt extending help to other countries so that delays experienced by some developing countries could be avoided.

Various thematic maps for practical planning having optimisation of geo-scientific data, have assumed great importance in recent years. Rapid stride has been made in the use of remote sensing techniques, Landsat and MSS data in mineral exploration, land-use planning, rural development, etc. The various thematic maps prepared for different purposes need proper compilation base for interpretation and utilisation. The countries like UK, Canada, Australia, etc., which have reached fair degree of development and sophistication in this field could attempt dissemination of the techniques to the other countries in the Commonwealth

b) Data Processing

The Geological Surveys of the Commonwealth countries have collected valuable and tremendous amount of geoscientific data which are stored in the traditional form of reports and maps. Need for storing and retrieving this data in an easily retrievable format taking into consideration the applications of computer techniques, has assumed very great importance. Many surveys are also attempting to digitise the maps. A close cooperation between the Commonwealth countries (developed and developing) in this field would be very useful, important and beneficial.

c) Sophisticated Instrumental Analyses and Usages

The laboratory and laboratory-cum-field techniques in the geo-scientific fields have developed at a tremendous rate in the developed countries. These sophisticated techniques have a direct bearing on precise determination of the parameters of mineral resources in terms of their origins, mode of occurrence, impurities/by-products, exploration clues, exploitation constraints, estimation of grade-wise reserve and so on. Commendable advances have taken place in remote sensing techniques, geochronological and isotope techniques, geophysical and geochemical techniques, etc. Introduction of sophisticated techniques and instruments for complex analytical methods, computerised data processing techniques, etc. have become important. With the sophistication of instrumentation techniques, the need for maintenance of advance version of sophisticated analytical instruments has also arisen. Since such instruments are not manufactured in the developing countries, lack of facilities for servicing and repairs of sophisticated equipment and absence of basic maintenance facilities have been cited by the Heads of Geological Surveys as an important factor for poor utilisation of such facilities. They had called for regional cooperation for effective utilisation of facilities and consultation with the experienced geological surveys and developed countries before going in for further sophistication. The Heads of Geological Surveys have also supported better communication and interaction between supplier and user of such equipment so that the suppliers may build better research and development (R & D) facilities. Some sort of cooperation among the Commonwealth countries in this field would be welcome.

d) Comparative Study of Classical Geoscientific Areas, Precambrian Shield Areas, Sedimentary Basins, Younger Fold Belts, etc

Comparative study of the important geoscientific areas classical in global context, for elucidating stratigraphic, structural, geological, geotectonic studies, etc., is vital for understanding the processes operative in the crustal formation, mineral deposit, rift system etc. The rift systems of Africa and Europe have been directed to understand the mechanics of crustal blocks, fractures and attended volcanic ejection of mantle material, ocean floor spreading, movement of plate margin, evaluation of the history of the continents, etc. Indepth study of such features and related phenomena under the aegis of Commonwealth Science Council would be appropriate. The programmes could be drawn in a manner that the classical/type areas are developed with equal benefits to the cooperating agencies.

e) Environmental Geology

Environmental appreciation and land-use planning, utilisation of locally available raw materials for industries, rural oriented appropriate technology, etc., are vital for development of backward countries within the Commonwealth. As stated in the introduction, 29 countries out of 48 in the Commonwealth fall under low and middle income level with GNP growth being marginal. Alternative source of energy, augmentation of water, power and mineral resources are some of the areas under which the rural population could be brought above the minimum standard of living. Many of the Commonwealth countries are devoting very great importance for the rural upliftment and their developmental plans are designed in this direction. The geoscience disciplines offer significant scope for closer cooepration among the Commonwealth countries, and interaction of the field of environmental approach from the beginning of a project to its end, would be very beneficial.

f) Utilisation of Low Grade and Complex Ore Deposits

All the countries are not endowed with abundant mineral potential. While some countries are having high grade deposits of certain minerals they are also faced with marginal or low grade deposits of certain other types of minerals which they are not able to utilise due to lack of proper technology for beneficiation and processing. Again some countries are having good multimetal deposit but they are not able to exploit the same due to lack of proper metallurgical techniques for separating individual metals from the complex ore types. Therefore some amount of regional cooperation under the aegis of Commonwealth Science Council in this direction would be beneficial. Perhaps, bilateral/multilaterial cooperation programmes among selected Commonwealth countries which are facing such problems may be considered by mutual consultation, and then further, the help of some developed countries in the Commonwealth may be sought for solving such problems.

9. The need for interaction, training and exchange of scientists among the Commonwealth member countries arises from:

(a) The global nature of geosciences - need for interaction among scientists (both on land and off shore).

(b) Acquiring of updated methodology and technology for precision, new data and better interpretations - through training and interaction programmes.

(c) Promoting scientific contacts between developed and developing countries for ultimate objective of fruitful collaboration, cooperation, consultancy, transferring know-how to other developing countries.

(d) Cooperation with International Scientific bodies/forums and sister surveys/institutions to represent national views and enter into effective dialogue on matters of mutual interest, (eg. with respect to UN, UNESCO, ESCAP, IGCP, CGMW etc).

10. Exchange visit of Scientists

There has already been exchange visit of scientists under the aegis of inter-country and bilateral S & T agreements on Governmental basis. Short duration visits of scientists are also arranged for mutually beneficial subjects on appropriate financial arrangements. India has agreement with the Academy of Sciences, USSR, China and other east Europian countries through the Indian National Science Academy (INSA). In the case of other countries the Department of Science & Technology (CSIR) processes such visits at Governmental level under the various existing S & T bilateral agreements. As far as the geoscientific aspects are concerned the GSI plays a major role in receiving the scientists on exchange basis. Such programmes of exchange visits have already been processed. Apart from these, some scientists especially university professors, have visited India under programmes processed by the University Grants Commission. The Commonwealth Secretariat may function as the Nodal Agency for processing such exchange visits among the Commonwealth countries.

This programme could be initiated on an experimental basis for 3 years and could be further extended based on the results.

11. Training of Scientists

Training of Scientists assumes very great importance in up-dating the knowledge of the scientists. Government of India has been providing training (both short term and long term) to the nominees of the countries within the Asian region and other on request. 10 placements in the GSI Training Institute have been set apart for nominations of ESCAP member countries every year for the Annual Orientation Training Course for the newly recruited officers. The countries which have availed our offer so far are Vietnam, Laos, Phillippines, People's Republic of China, Nepal, Afghanistan, Burma and Sri Lanka. Bangladesh and Iran have also indicated their desire to avail this offer in the near future.

Apart from the regular training course cited above GSI also provide short term on-the-job training in specific fields on request. A Geophysicist (Inst.) from Ethiopia had undergone training in GSI under this scheme. A request from Zambia has also come for providing short duration training in Mineral Exploration. Similar requests from Afghanistan and Sri Lanka had been received for training in Mineral Exploration, Museum Technology, etc. under Colombo Plan processed by the Ministry of Education.

The training facilities available in Commonwealth countries may be collected by the Secretariat and scientists desirous of training could be sent with funding support from CFTE, Colombo Plan, etc. A suggestion has been made in the meeting of the Heads of Geological Surveys of the Commonwealth countries that the candidates selected for training should be sent to such countries where the medium of instruction is the same as that of the sponsoring country and also called for utilising training facilities available within the Region. They have drawn example of good training facilities available in Nairobi (African Region), Asian Institute of Technology, Bangkok (Thailand), Kuala Lumpur (Malaysia) a number of institutes, universities in India and West Indies. Greater interaction among survey, exploration, exploitation and utilisation agencies has also been suggested. In-service training of Geologists and Technicians by encouraging a programme of exchange of personnel has also been suggested to determ ne which of the Surveys in a Region can offer useful training. Exchange of personnel and collaboration between sister surveys for availing valuable practical experiences has also been suggested. In this connection, closer cooperation between Commonwealth Geological Surveys by exchange of experts or other valid mutually agreeable means needs strengthening and the Commonwealth Liaison Officer (Geological) can play a significant role in this direction.

This would be a continuous programme designed for transfer of know-how.

12. Organisation and participation in Seminar/Workshop, etc

A number of workshops are organised by the United Nations Organisations, such as UNDP, ESCAP, RMRDC, UNIDO, UNESCO/IGCP etc. in different countries. Whenever such workshops on geoscience; are held in India, the GSI is normally called upon to shoulder major responsibility in organising them. Mention may be made of the Workshop on 'Mineral Resources Evaluation' organised by the Commonwealth Geological Liaison office and held in Bangalore in March 1979, in which candidates from a number of Commonwealth countries took part. Indian scientists also take part in the various IGCP field workshops/RMRDC workshops held outside India. Such workshops give the participants a platform for exchanging views which goes a long way in up-dating the scientific knowledge.

This would be a continuous programme and CSC should encourage and fund such symposia/workshops.

13. Consultancy

Though consultancy has not been undertaken by the GSI directly, our scientists are deputed for assignments abroad through Water and Power Consultancy Services (India) Ltd. (WAPCOS), Rail India Technical and Engineering Services (RITES), etc. for undertaking projects in the neighbouring countries. Such expertise/consultancy has been provided to Nepal, Bhutan, Sri Lanka, Vietnam, Philippines, Burma, Tanzania, Algeria, Irag, etc. among other countries. In addition, our scientists are also sent on deputation under UNDP, ITEC and bilateral programmes for assignment, by which not only our expertise is imported to the countries in need, but their personnel also get trained.

Among the Commonwealth countries a high level of geoscientific expertise is already available in UK, Canada, Australia, New Zealand and India. The Commonwealth Secretariat could pool the resources available in these countries for undertaking consultancy projects in the other developing countries. In fact, the Commonwealth Secretariat could impress upon the UN to draw the expertise available in the above mentioned countries for UNDP assignments in other Commonwealth countries. This process would ensure a class cooperation amongst the Commonwealth countries themselves because of their common administrative bondage and language.

This programme could be on continuous basis.

14. Exchange of date

Scientific data could also be disseminated by exchange of publications and journals. GSI maintains exchange with 288 organisations/ institutions in 57 countries on a regular basis. Similarly, GSI also receive information from other countries. Commonwealth Secretariat could support a project for publishing a Bibliography of all the publications coming from the Commonwealth countries which could be distributed amongst the Commonwealth countries. This aspect could be taken care of by the CGLO as part of its activity.

This programme also would be on continuous basis.

ABBREVIATIONS

CGMW	-	Commission for the Geological Map of the World
ESCAP	-	Economic and Social Commission for Asia and the Pacific
IGCP	-	International Geological Correlation Programme
UN	-	United Nations
UNESCO	-	United Nations Educational, Scientific and Cultural Organisation

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INTRODUCTION

The Commonwealth Science Council wish to generate an atmosphere conducive to the advancement and dissemination of science in the Commonwealth which will assist in the logical formulation of appropriate research policies. Since natural conditions and development prospects vary from country to country, apart from other important constraints, (e.g. financial), no one policy will be appropriate for all member countries and planning must therefore be specific, primarily on a country basis but having regard to regional considerations.

The preparation and implementation of a co-ordinated research programme must take account of:

(i) The importance of the specific topic (hydrogeology) for economic and social development of a country.

(ii) The consequences of significant development which may result from innovative ideas.

(iii) Regional factors.

(iv) The various institutions and organisations which are responsible for determining science policy and carrying out scientific programmes of work.

(v) Availability of scientific manpower, facilities and financial resources.

This Report will present a brief global and regional review of groundwater occurrence and development emphasising key issues in developing countries and in particular regions, geohydrological and geographical. It will discuss general research topics and policy training but it is assumed that more precise planning will need to be country or region specific.

GLOBAL AND REGIONAL REVIEW OF GROUNDWATER OCCURRENCE AND DEVELOPMENT

The importance of groundwater as a resource depends primarily on its availability, quality and economics of development and on equivalent comparisons with alternative water resources. Social and political considerations include a country's level of development. Water demands change with the stage of development and the importance of a particular resource can change accordingly. For example, groundwater has particular value as domestic supply for the rural populations of the developing world largely because of its dispersed occurrence and generally low cost of development. With increasing economic development and urbanisation, a greater preference for piped and distributed water supply is manifested and finance is more likely to be available for the technically more convenient (from a design viewpoint) but generally more expensive surface water schemes. The choice of a large multipurpose dam is partly such an issue but there is also often an element of political motivation in decisions to build 'these temples of the

modern world', as they have on occasions been described. Where a greater concern exists for environmental and ecological issues, groundwater with its lesser impact may then be preferred. This viewpoint may well be the expression of common feeling in developing countries with large rural populations and strong traditional values, particularly in respect to land.

Methods of assessing the importance of a water resource range from a qualitative and simplistic discussion of its potential or current use to more quantitative analysis usually expressed in cost benefit terms. An economic analysis is generally used but there is an obvious need to apply methods which also reflect the value of environmental and social objectives. The latter may be translated into economic terms although this is clearly difficult. An alternative method is to separate and define these objectives in order to analyse in detail the potential impacts of varying options and select accordingly.

The evaluation of groundwater resources is a process that must take account of the scale and value of the demand, the complexity of the hydrogeological context, and of other considerations, such as the need to make adequate comparisons with alternative sources of supply and the predicted effects of development. Exploration of groundwater occurrence may be regarded as an initial phase in evaluation and the degree of additional information needed on any identified resource will relate to those factors already mentioned. Difficulties may arise in deciding such issues, particularly for domestic supply, where the value of the resource is 'social'. An example may be quoted in small limestone islands at a low level of development which would find it hard to justify the expenditure on detailed studies, such as modelling, needed to optimise development of a complex coastal aquifer occurrence. More cost-effective techniques are needed than are at present available.

Conservation is a primary requirement in development, and merits increasing emphasis. In practical terms, it may be defined broadly as efficiency in use. The methods and objectives will vary with the type of development. Problems of wastage are likely to be a major concern in large scale, high cost development for urban supply. In irrigation schemes, conservation may be most necessary because of limited water resources or because of the potential ill-effects of excessive application such as rising water tables and soil salination, leaching of nutrients etc. Conservation in coastal aquifer developments permits maximum abstraction consistent with defined and acceptable levels of sea water intrusion into the aquifers or other effects which may relate to the disturbance of coastal ecology or land subsidence. Conservation must always be practiced when resources are being mined. The future values of such resources are not readily predictable and longer term considerations should apply. Conservation *in cost* to permit a minimum but efficient service for all is the key to the provision of water supply to the rural communities of the developing world and groundwaters' advantages in occurrence and use seem likely to give it pride of place in realising this objective. Although the cost of individual water points is low, the total investment to meet minimum service targets will be very large indeed. Low borehole/wells costs must be combined with improved designs for efficient, maintenance-free operation. The search for the VLOM* handpump and the application of animal, solar and wind power are related aspects.

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* Village Level of Maintenance

The creation of a commitment by the local community is another essential ingredient, more obviously applicable to rural communities, but not exclusively so, and particularly relevant in relation to groundwater use. It may result in a close involvement in construction and maintenance operations of simple supply sources but equally important is the need to obtain a proper understanding of the value of water supply and the necessary safeguards for proper use. Sanitation, hygiene, protection from pollution and environmental issues are also closely related.

Finally, reference must be made to the role of the hydrogeologist. To date, the hydrogeologist has had in the main a professional and technical role in resource evaluation studies without significant involvement in project management. The common complexity of a groundwater resource both spatially and in time-related response characteristics will inevitably reflect in development inefficiency unless hydrogeological knowledge is continuously available. The result of an expanded role would hopefully be seen in (i) the increasing, and some would say overdue, recognition of the value of groundwater as a supply source, and (ii) major cost savings in development. For more effective involvement in development, the hydrogeologist will also need to develop an awareness of the technological, sociological and financial constraints of the various communities with which the work is associated.

Groundwater: Intrinsic Importance.

The main characteristics of groundwater which give it particular importance are listed below.

Widespread occurrence

Large natural storage

Inbuilt protection from pollution and evaporation

Development costs generally lower than surface water schemes, particularly when the latter require construction of dams or reservoirs.

Flexible and phased development is feasible

Environmental impact of development generally low and sometimes positively beneficial.

The widespread occurrence of groundwater on land needs little emphasis. What is generally less well known is the occurrence and potential importance of submarine discharge. Whatever the value of any such resource identified, it can be assumed that assessment will not be easy. Offshore development is bound to be expensive and optimal coastal aquifer management usually requires sophisticated control techniques. On land the widespread occurrence of groundwater is more relevant to the supply of rural communities in developing countries, particularly in the more arid regions and for poorer communities.

The importance of natural storage has particular relevance in those regions subjected to frequent and protracted droughts, such indeed as that currently afflicting large areas of Africa and South Asia. The full potential of groundwater storage can only become apparent when account is also taken of management techniques or the feasibility of induced or artificial recharge. Such calculations are more readily applied to local situations but some indication of the relative significance of groundwater storage can be obtained

from global and continental statistics. Table 1* shows the enormous volumes of stored groundwater although it should be recognised that water in deeper levels would be costly to utilise and is likely to be saline.

Table 1. Estimated World Water Supply and Budget.

Water Occurrence	Volume (km^3 10^3)
Land Areas:	
Fresh water lakes	125
Saline lakes and inland seas	104
Rivers (average instantaneous volume)	1
Soil moisture and vadose water	67
Groundwater to 4000 m	8,350
Ice caps and glaciers	29,200
Total in land area	37,847
Atmosphere	13
World oceans	1,320,000
Total all items	1,357,860

Some indication of the importance of groundwater, including the permanent storage and the annual runoff, can be obtained by comparisons of current and project demands (Table 2) compared with runoff volumes (Table 3), both being expressed per capita in m^3/day. Stable runoff is primarily base groundwater flow with subordinate amounts obtained from regulation by lakes and reservoirs

The eventual inadequacy of stable runoff to meet total per capita demand should be recognised without taking account of the imbalance of distribution. On the assumption that increased surface storage is not generally feasible because of cost and impact, deficiencies must be met by conservation or an increase in groundwater yield over and above stable runoff. The additional demands could be met either by reduction of evaporation or abstraction from permanent storage. Criteria for use of permanently stored water are debatable issues.

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* Data in this and other table are from Van Der Leeder, F. Water Resources of the World, World Information Centre Inc., New York, 1975.

Table 2. Per Capita Water Demand in m^3/day.

Year	Domestic	Industrial	Agricultural	Total
1975	0.15	0.12	1.32	1.59
2000	0.34	0.34	1.64	2.32
2030	0.49	0.49	1.92	2.90
2060	0.52	0.52	1.92	2.96
2090	0.54	0.54	1.92	3.00

Table 3. Per Capita Water Resources.

	Runoff volume per capita, m^3/day	
1969	Total	Stable
Europe	13.3	5.8
Asia	17.6	5.4
Africa	33.6	15.1
North America	52.3	20.9
South America	153.7	57.8
Australia	29.9	7.5
Total Land area	30.0	10.8
2090 projection		
Total land area	5.1	1.8

The natural protection of groundwater from evapotranspiration losses or from surface contamination is mainly provided by the overlying soil and vadose zones. The particular case of contamination by sea water intrusion is generally a consequence of overdevelopment and methods to remedy or control such effects are well understood. More insidious effects occur in association with developments in sanitation and the increasing use of pesticides, herbicides and other agrochemicals.

Development costs cannot be categorised simply but there are many aspects of groundwater occurrence which enable these to be kept low. Groundwater has its own inbuilt distribution system; it lends itself to phased and flexible development and there is commonly little or no need for treatment. Shallow groundwater which occurs over extensive regions can be developed cheaply by local communities using human resources and simple technology. Environmental effects of groundwater development are usually small and certainly likely to be less than those from the construction of dams, reservoirs, storage tanks, treatment plants or major pipelines. Adverse effects do occur such as ground subsidence, or indirectly, such as soil erosion following overgrazing around water points. But such effects can be controlled or avoided with better management. On the positive side, the use of shallow groundwater to support trees and other vegetation can combat desertification and perhaps with favourable circumstances and on a sufficient scale even exert an influence on climate.

Geohydrological Regions.

The recognition of geohydrological regions follows from the proper understanding of the basic controls of geology and hydrology. They form a useful basis to discuss individual case histories and the practical value of the correlation lies in the impetus to extrapolation of results. Four major sub-divisions are shown on the included World Map* - fold mountain ranges, basement shield, sedimentary basins and volcanic terrain. In South America, Africa and S E Asia, the sedimentary aquifers are sub-divided according to whether the main supply aquifers are consolidated or unconsolidated. For reasons of scale, a fifth subdivision of importance is not shown, specifically that comprising small oceanic islands. Such regions do have special problems associated, commonly a deficiency of water supply and groundwater inevitably at risk from saline intrusion.

Fold Mountain Belts

Fold mountain belts, particularly those of more recent age form upland areas, often of high relief and with variable rainfall. Surface water supplies may be readily accessible but groundwater is commonly utilised, particularly for domestic supply and its importance increases with aridity and the seasonal variability of rainfall. The complex geology and relief is reflected in groundwater occurrence with aquifers ranging from consolidated bedrock to younger alluvium. Conjunctive use of surface and groundwater is to be anticipated and the possibility of artificial recharge may exist. Fissured aquifers with thin overlying soils constitute a high hazard to pollution, as do alluvial aquifers with shallow water tables and/or close connection with surface water.

Basement Shield

Vast areas of Africa, South America and Asia are floored by crystalline basement rocks and although associated aquifers are not highly productive, they are of considerable importance, particularly for rural supply. Aquifers occur in the weathered mantle and/or the fractured bedrock and two aspects of critical importance are the calculation of regional recharge and the

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* Reproduced from Wright (1983), Groundwater Development, in World Water '83, London, Figure 5.

methodology to optimise usage, recharge and productivity. The large diameter well is of particular importance because of the generally low permeability of these aquifers but research is needed on extending its range of utilisation. Techniques such as geophysics are valuable aids to locating deep weathering zones but are costly and the results, particularly in terms of permeability and water quality, are as yet unreliable. Recharge evaluation becomes more critical in highly populated areas or where an added usage such as agriculture is apparent. More effective techniques of abstraction from thin, extensive but low permeability aquifers could result in enhanced recharge and increase their importance.

Volcanic Regions

Widespread volcanic regions commonly display variable aquifer conditions reflecting the complexity of the geology. Water quality in volcanic rocks may also be variable and noteworthy in the presence, often to excess, of minor elements such as boron or fluorine. Some aquifers are extremely porous and permeable due to the presence of fissures and cavities and comparable in behaviour to karstic limestone; others have low to negligible values of these parameters, notably primary pyroclastic deposits which tend to be ill-sorted. Basalt sequences often have a widespread uniform layering and the older occurrences, such as the Deccan Plateau basalts of India, have a weathering mantle which behaves hydrogeologically much as does the regolith overlying basement shield rocks. Acid volcanic sequences are generally more complex.

Sedimentary Basins

The sedimentary basins of the world contain its most important and productive aquifers. The regional basins shown on the World Map store enormous volumes of water and may be differentiated from more localised sequences in valleys, fault troughs or upland coastal marginal basins. The older basins and those containing marine formations are generally consolidated in consequence of diagenesis. Unconsolidated sediments are more common in younger alluvial basins with terrestrial sediments. Overall thickness of sediments in the regional basins varies but some attain thousands of metres. Water quality tends to deteriorate with depth but can be found fresh to below 1000 metres. Fresh water in storage largely comprises water from older pluvial periods.

Sedimentary basins with aquifers in consolidated rocks. These basins are generally of older rocks, Palaeozoic or Mesozoic, and aquifers occur more frequently under artesian conditions. In the arid regions, recharge may be small or negligible but an important aspect of development of artesian aquifers is the likelihood that they may be in current equilibrium with modern recharge, small though it is. Artesian aquifers are more sensitive to development because of their low storativity, and special consideration is needed where significant development has occurred in the past at natural discharge locations. If the aquifer is demonstrably at equilibrium with current recharge, there is probably greater merit in limiting abstraction to the same level thus avoiding putting existing developments at risk and ensuring long term continuity of use.

Sedimentary basins - unconsolidated. The basins containing sequences of largely unconsolidated sediments are generally of more recent age (Tertiary-Quaternary) and the sediments are mainly terrestrial, sands and clays with occasional lacustrine or soil carbonates. The various lithologies tend to be lenticular, and in consequence the longer term hydrogeological response is essentially phreatic, even in thick multiaquifer sequences. There are significant developmental differences according to whether occurrence is in arid to semi-arid or humid to sub-humid regions. Examples of the former include the Sirte and Chad basins of North Africa and some of the Andean marginals basins of South America. The latter type is more widely distributed in South and South East Asia, central Africa and northern South America. Sedimentary evolution in the thicker sequences is complex with structural controls which may be related variably to older 'basement trends' or recent plate movements.

The groundwater in the arid zone sedimentary basins has value in a primary agricultural and domestic supply context and will relate to overall socio-economic developments. Enormous developments are current and planned, for example, in the Sirte basin of Libya, financed from oil revenue. Initially agricultural developments in situ were carried out but the current planning is to pipe huge volumes to the coastal areas where the population is more concentrated. A mining approach to the development of regional phreatic aquifers is more justified than in the case of the artesian aquifers which are more sensitive in response. Aquifers in the sedimentary basins of humid regions are developed conjunctively with surface water and in the more populated areas, as in South and South East Asia, management issues are complex and often debatable. Tubewell efficiency is an important aspect in economic assessment and there is much ongoing research. The control of pollution or salination of soils is of increasing importance. Social considerations generally can have a major influence on cost effectiveness of development.

The thin, inextensive sedimentary aquifers are locally very important, particularly in arid regions. The scope of various development techniques such as infiltration trenches, induced or artificial recharge, traditional ganat constructions, sand dams, etc. have yet to be fully explored.

Management Aspects: Pollution and Artificial Recharge.

Groundwater is usually regarded as a safe source and there is in consequence a general lack of awareness of the possibility of pollution. The grosser forms of contamination, such as sea water intrusion into an aquifer, are easily recognised and understood. More insidious and potentially more dangerous forms of pollution exist and are likely to extend and increase their effects during the Decade unless adequate protective measures are adopted. All forms of urban and industrial pollution of groundwater are as likely to occur in the developing as in the developed world, although obviously to a lesser extent. In certain respects however, developments in the former region are at greater risk, mainly in respect to the occurrence of large numbers of low cost boreholes of simple design abstracting from shallow water table aquifers and providing untreated and unmonitored supplies to dispersed communities. The most notable risk is of faecal pollution carrying pathogenic bacteria and viruses, and nitrogen compounds derived

from unsewered sanitation systems, mainly pit latrines. The design of latrines and their location in respect to a water supply source must relate to the geohydrological environment and the hydraulic loading. Although the basic principles of purification of voided human waste are generally understood, precise quantification of safe distances cannot always be stated with certainty and further research, case studies and general monitoring is needed of high risk environments. These occur, for example, where there is a thin cover of unconsolidated material (<3 m) overlying a fissured bedrock aquifer or where the groundwater table is seasonally or perennially shallow (<3 m).

Nitrate pollution of groundwater from the same source is not so immediate a hazard but is likely to be more widespread and persistent. Processes are complex and in consequence difficult to quantify; effects of high nitrate concentrations are also uncertain. Nonetheless it must be expected that unsewered sanitation schemes are bound to have a major effect on nitrate concentrations, especially in arid regions with little dilution occurring in the aquifers by throughflow. In similar context must be included risk from intensive ranching and in particular where soil erosion following overgrazing has reduced the thickness of the protective soil shield.

The second major source of potential pollution in the developing world is likely to relate to agriculture. The growing emphasis of intensive and irrigated agriculture is resulting in considerably increased use of fertilisers and agrochemicals. Irrigation by wastewaters treated in unlined oxidation lagoons is becoming more frequent in arid regions, and shallow aquifers can be at risk in different ways either by direct seepage of raw water or by leached solutes in irrigation return waters. The urgent need for improvements in sanitation and increase in agricultural productivity in most developing countries is bound to result in added groundwater pollution risk. Some types of pollution, e.g. nitrate will be slow to appear but would be very persistent. An awareness of the nature and scale of the problems and the constraints imposed by adverse hydrogeological conditions is needed. Detailed studies are needed in representative or high risk areas with consideration of the efficacy of remedial measures. The various remarks above apply to protection of the groundwater source and not that of transported water which is an issue of hygiene.

Artificial recharge. The surplus of total runoff over stable runoff (Table 3) is an indication of a large potential resource which is becoming increasingly difficult to exploit by storage dams or reservoirs. Artificial recharge to groundwater is a possible answer but the method is not generally simple and is often costly.

Enchanced recharge has been a traditional practice mainly in arid zone countries by construction of check dams to retain flood flows, for agriculture and/or groundwater recharge. Modern technology can extend and improve such practices. Enhanced recharge by management of storage in regionally extensive aquifers has yet to be practised to any extent but has particular applicability to thin aquifers with low storativity and shallow water tables. Feasibility may depend on the ability of modern techniques to obtain widespread lowering of water tables without the requirement of large numbers of production wells.

Artificial recharge using constructed basins or injection wells is a recent technology requiring considerable care in planning. Recharging waters may be natural flood flows or runoff from artificial structures such as airport aprons. Apart from increasing total storage, other potential uses include prevention of saline intrusion, reduction of pumping lifts and prevention of land subsidence. Pre-treatment costs are often the most critical factor.

Summary of Key Issues.

Fold Mountain Belts

Conjunctive use of surface and groundwater.

Potential of induced or artificial recharge.

Pollution hazards in thin valley floor sediments and in fissured aquifers.

Basement Shield

Problems in calculating recharge to these thin extensive aquifers of low permeability.

Methods to optimise development, particularly in the context of rural supply and small scale irrigation. Consideration of renewable energy systems is important.

Role of higher technology (geophysics, remote sensing) in resource investigations.

Environmental hydrochemistry, pollution risks and protective measures.

Volcanic Terrain

Environmental hydrochemistry and pollution hazards.

Sedimentary Basins

(i) Regional

Behaviour and developmental implications of artesian and phreatic aquifer systems. These issues range from mining resources in the arid to semi-arid regions to management and socio-economics of multi-aquifer sequences in humid regions.

Information on climatological patterns deduced from variations in water ages in unsaturated and saturated zone sequences.

Quantification and importance of current recharge.

Development efficiency and economic issues of the large capacity tubewells.

Utilisation of brackish and saline waters.

(ii) Local

Conservation, i.e. efficiency in use of limited resources.

Scope of various development techniques including induced or artificial recharge, infiltration trenches, ganat constructions, sand dams, etc.

Pollution risks and protection measures.

Small Island Water Resources

Potential and development of groundwater in small islands. Problems of seawater-freshwater relations, pollution considerations (particularly in low-lying limestone islands), legislation issues, ecology and environmental issues. Feasibility and scope for modelling methods in complex systems with waters of different density for optimised development and flexible control.

CONSIDERATION OF SPECIFIC FOCI FOR COOPERATIVE RESEARCH

Hydrogeological investigations in developing countries are mainly carried out by government service departments and bilateral and multi-lateral aid agencies. Other research work is carried out at Universities or Research Institutes. The majority of investigations are development oriented and research studies are applied or strategic in nature and generally short/medium term. An example may be cited of the World Bank Global Hand Pump Project.

A summary of research programmes being carried out in the developing countries of the Commonwealth has been prepared by the Commonwealth Science Council. Hydrogeology as such is rarely mentioned in the listings but 'hydrological' research is carried out in Faculties of Agriculture, Civil Engineering and Geology. Agricultural research includes soil-water management, particularly in the context of comparisons between irrigated and non-irrigated systems. Climatology is another topic (one University). Within the Commonwealth countries listed*, India/Bangladesh have 6 Universities carrying out research on hydrology in the Agricultural Faculty, and S E Asia, 1. Civil Engineering includes drainage, groundwater and water resource studies. Comparable figures are India/Bangladesh, 4 and S E Asia, 2. In the Faculty of Geology, hydrogeology is specifically mentioned only once but related aspects such as geophysics, sedimentation, geomorphology and structural geology could be regarded as ancillary subjects which have importance in relation to hydrogeology. On the basis of this broader definition, India/Bangladesh include 6 Universities/Institutes carrying out research, Africa 2 and S E Asia 2.

Key issues of research for various geohydrological regions have been identified above. The majority are appropriate for collaborative research programmes with the likelihood of important results accruing in the short to medium term. Skilled manpower would gain research experience with increasing capacity to adopt and adapt technology and generate indigenous technology. Some programmes could most effectively be implemented in a regional context, notably the study of basement aquifers in Africa and the problems of small island water resources. Selection of priorities (either from the lists shown here or other topics) and preliminary indications of finance and manpower availability can best be proposed by individual Commonwealth countries.

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* India and Bangladesh stand out by reason of the scope and depth of the work being carried out and in consequence should be considered more as a source of expertise for co-operative programmes than a recipient.

The collaborative research could be carried out by teams drawn from relevant government service agencies, Universities of Research Institutes within the 'host' country/countries combined with personnel from appropriate organisations in more advanced Commonwealth countries. Team inputs would be variable in accordance with need. The first phase would include assembly of background data and literature search leading to a detailed and costed plan of action.

Another approach could include the setting-up of regional centres in selected Commonwealth countries in which staff could carry out appropriate research, give guidance on regional project coordination, assist in training, give specialist advice etc. The arrangement would also facilitate interdisciplinary collaboration. Such an approach would be particularly valuable in regions where constraints of finance, remoteness, lack of trained staff, etc. prevent adequate basic studies being carried out. The island regions of the South Pacific and Caribbean would have particular relevance in this respect.

Acknowledgements.

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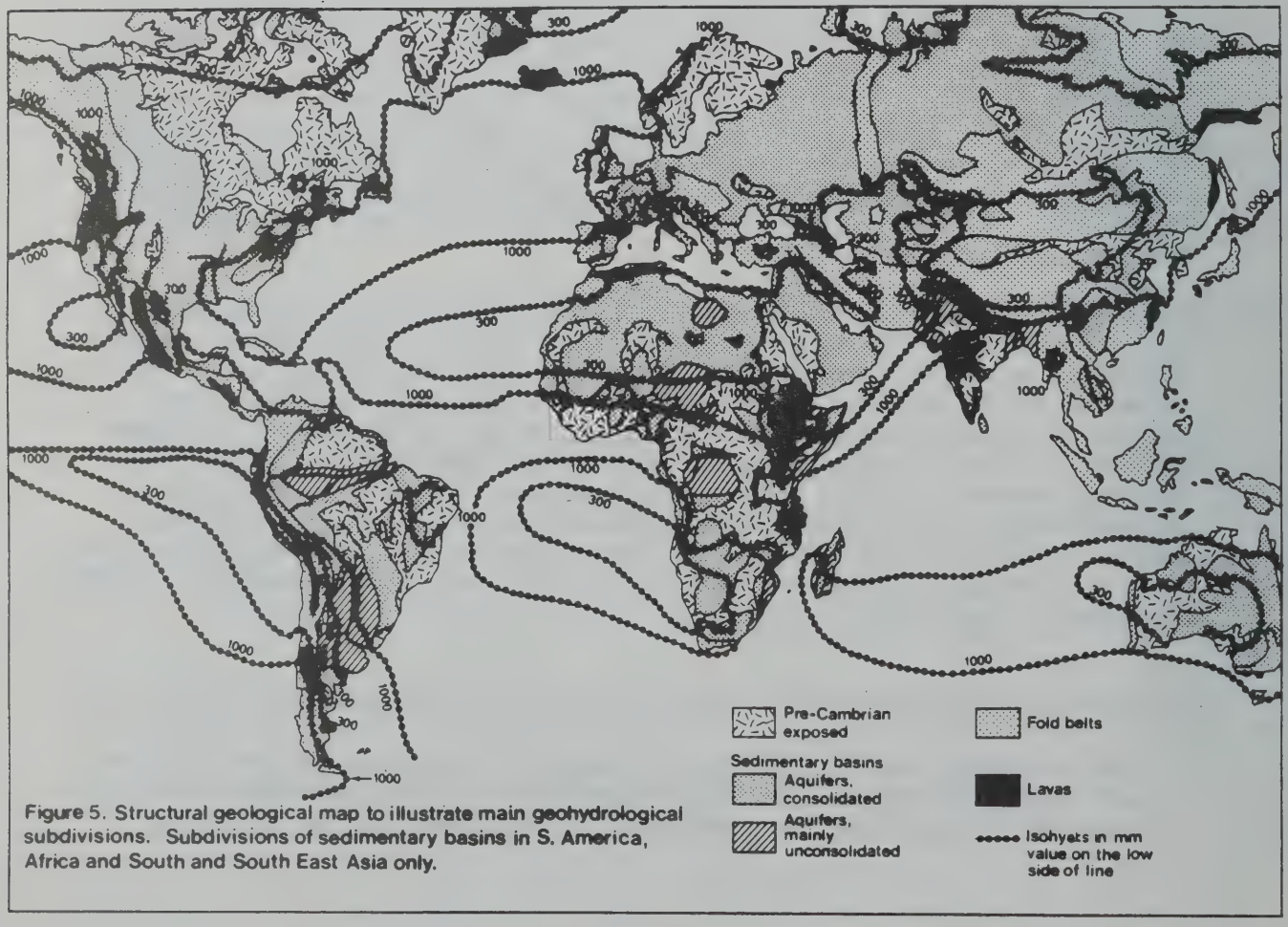

Figure 5. Structural geological map to illustrate main geohydrological subdivisions. Subdivisions of sedimentary basins in S. America, Africa and South and South East Asia only.

Perspective on New Materials and Materials Technologies

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SUMMARY AND CONCLUSIONS

The following are general considerations underlying potential developments in engineering materials and materials technologies. We stress the view that the requirements for new materials and new materials technologies spring from the functions required of engineering structures, such as improved performance, integrity and reliability. Considerable benefit lies in improving the performance and behaviour of conventional materials, for example steels and other alloys, in which there is already an accumulation of metallurgical knowledge, an existing capital investment, production capability and a continuing world demand.

Although there are euphoric claims about the future of new materials such as fine ceramics and composites, their applications lie predominantly in the high technology or value added end of the engineering product market and unless the intending participants in an R&D collaborative network have a suitable industrial base to support the implantation of such materials, it would be ineffectual to move along these directions.

Finally we propose and illustrate a specific procedure for engaging in materials R&D and suitable for countries with different levels of industrial development. This lies in stimulating R&D in generic subject matters which represent mainstream activities: in turn, these could provide spin-off into a variety of industries and technologies throughout the entire raw minerals - advanced materials spectrum, ranging from improvements in mineral extraction processes, such as ore grinding and metals recovery, to engineering component design for advanced applications. In this way, participants in such a scheme should derive benefit appropriate to their specific resources and industrial potential.

1. For our purposes, the term "material" denotes physical matter which is used to construct things - machines, devices, habitations and other objects required by Man in the course of everyday life. This covers a wide spectrum of materials types and usages, from the very refractory tungsten metal used in incandescent light bulbs to timber used in habitations. In the Table which follows, we list the major classes of materials, and give some examples, noting the principal properties and some applications. Here, the first four classes refer to the materials which have the highest promise of value added improvement and information content, with a high latent economic gearing factor. The common characteristic of the classes of materials that come under the headings of construction moterials, timber and paper is the large volume production. The first four classes of materials are often referred to as engineering materials since they form the basis of engineering structures. This is a simple convention for distinguishing them from the other classes of more common materials. The present commentary will be confined to a discussion of these engineering materials.

In making a comparative analysis of the production and usage patterns of these classes of materials for the industrially developed market economies and the less developed countries, clearly engineering materials are used to a much less extent in the latter countries. Judging from figures derived from data published by the United Nations Industrial Development Organisation, (1973) there is a vast preponderance of consumption of all materials in the developed market economies, as contrasted to that in the developing economies. Another interesting observation is that the percentage increase in production in engineering materials in the developing countries is at least as large as the increase in the other materials categories. Furthermore, in recent years there has been a definite trend in the more mature economies away from tonnage production of engineering materials, towards smaller volumes of materials with more critically assessed applications and having high value added input, for example, in electronic and in aerospace applications. Both technological changes and changes in socio-economic demands are imposing shifts in the relative importance of the various classes of materials in the different communities.

2. That which distinguishes materials from the other technologies and sciences which are the subject of intense current attention is that materials are not an end product in themselves - they find their worth only in so far as they permit an engineering structure to fulfill its functions. In this sense then, materials have (sometimes literally) an underpinning role, they provide the framework for mechanical and chemical engineering and thus they represent essentially an enabling technology. Hence any considerations of materials innovations must relate to the purpose of the end product: thus the mainspring, the determinants of future materials developments are the specific requirements of engineering structures. These functional characteristics can be listed as follows:

(i) Improved performance.
(ii) Improved durability.
(iii) More effective processability.
(iv) Consistent quality and reliability.

TABLE

Materials used by Society

Classes	Some Examples	Principal properties of characteristics	Examples of Usage
Metals & Alloys	Steels, superalloys, light alloys	Strength, toughness	Automobiles, aircraft, pressure vessels
Ceramics & Cermets	Alumina, silicon nitride, metal carbides	Temperature & corrosion resistance, high hardness	Furnace refractories, engine components
Plastics & Elastomers	Polymers, rubbers polyurethanes	Strength, corrosion resistance, low density	Pipes, panels, process plant
Composites	Fibre reinforced plastics, metals or ceramics	High toughness; high strength/weight	Aircraft and other transport components
Construction Materials	Building stone, cement	Durable, plentiful supply	Building habitations, roads, bridges
Timber	Wood, wood composites	Ease of fabrication, strength	Furniture, buildings
Fibre	Cotton, nylon, glass	Diverse; manufacturing and handling ease	Textiles, fibre/ plastic composites
Paper	Paper, paperboard	Diverse	Printing, decorating

(v) Light, energy saving structures with better strength to weight ratios.
(vi) Specific (often exotic) characteristics of new materials for technologies of the future.

These general characteristics constitute a pattern of attributes that define the nature of specific materials innovations. They relate to all the major sectors of a modern technological economy - in the transport sector, in process plant, in petrochemicals, chemical engineering and power engineering.

3. Before discussing the types of new materials which will be generated by these requirements, we emphasise that the notion of "new materials" also includes conventional materials with improved characteristics or performance. There is a strange fascination attached to the notion of miraculous new materials inventions - this constrains creative thinking along the lines of producing innovative materials. Indeed, entirely new materials will be synthesised from their basic molecular structural units, for example, new organic materials. However, we stress that as much benefit is potentially available through improving existing materials. Thus, through the application of modern metallurgical principals, new high quality steels have been evolved known as HSLA (high strength low alloy) steels, which allow the use of reduced thickness of strip in automobile bodies; in this way, HSLA steel combats the competition from strong light materials such as plastics and composites. There are many opportunities in the materials technologies in such incremental improvements in properties as compared to the more risky direction of seeking a sharp discontinuous change or development. Indeed, in many of the examples we give below, the materials innovation is in fact a greatly improved conventional material.

4. We consider in a little detail some of the materials research opportunities and the new materials which will be spawned by the above characteristic requirements of engineering structures:

(i) Improved Performance

Economic benefit is obtained by improving the thermodynamic efficiency of engines. This in turn requires the engine to operate at higher temperatures. Again, in manufacturing and production technology, there is a need for cutting and grinding tools with less wear and greater cutting speeds. Improved performance can be partially achieved by improving design but ultimately there are limits imposed by the nature of the material itself. Today we are witnessing a revolutionary move towards the development of suitable ceramic materials that will substitute for many of the metallic materials which lack the refractory nature, corrosion resistance and wear resistance of the ceramics. We have seen the development of high purity transparent alumina, which is being used in sodium vapour lamps; hexagonal boron nitride with potential in coating applications; reaction-bonded silicon carbide and silicon nitride which are used as replacement engine components; yttria-stabilized silicon nitride in ceramic turbine blades which permit a turbine inlet temperature of 1300°C; there are major developments in "sialons" with high strengths at temperatures as high as 1200°C - these are already being used as tips for rapid cutting tools, displaying a remarkably high performance. The excellent attributes of high hardness, heat resistance, thermal conductivity, low coefficient of friction,

corrosion resistance and very high strength are providing silicon carbide ceramics opportunities for applications, such as mechanical seals and bearings in engines and in pumps and agitators handling fluids which increasingly operate under harsh conditons.

In addition to the above applications in high performance situations such as ceramic engines, ball bearing and cutting tools, many other uses are being envisaged for the new classes of ceramic materials, as in new electronic materials. It has been estimated that when the new structural ceramics are proved, a potential market of 5 billion dollars will become available throughout the world.

(ii) Improved Durability

In this category, it is required that engineering structures perform at their maximum capability over a long time scale without failure. There are many aspects of materials developments which will lead to improved durability. For example, the common problem of corrosion of steels with the consequent need to replace components in engineering plants, costs the UK an estimate of 3 billion pounds a year. A recent assessment in the USA has produced a comparable figure of 4% of the gross national product. Furthermore the experts estimate that about one third of this could be saved by an improved transfer of current technology and an additional third could be saved by developing new materials protection technologies with suitable surface coatings and surface treatments that will combat corrosion. Other aspects of improved durability in machines refer to improvements in wear tolerance, in better joining technologies such as in welding and also in improved materials used as prosthetic implants. In the latter connection, we see new lines of research development in which it is hoped to use more ceramic components in bio-engineering applications.

(iii) Improved Processability

The shaping of conventional materials such as steels into components leads to considerable wastage through the use of cutting and turning operations. There are many opportunities in developing near-net shape processing techniques, in which the component is shaped to its near final form by processes such as sintering and casting without the need for extensive final finishing operations. This requires further research in CAD/CAM techniques for the design of shaping and forging dies: it requires further basic knowledge in high temperature sintering processes and the role of sintering additives and in addition, improvements in continuous casting operations. In the context of making improvements in conventional materials, there are potential developments in strip casting techniques combined with in-line rolling that will produce steel sheet for automotive and other applications. This holds a promise of enormous energy savings as well as the possibility of producing higher quality steel.

(iv) Consistent Quality and Reliability

Modern manufacturing technologies require materials with a highly consistent quality and reliability in order to avoid wastage during the manufactuirng process. This in turn entails the production of high quality starting stock, metals of high and

consistent purity and with metallurgical refinements. Engineering structures demand reliability in service and obviously the avoidance of catastrophic failure brought about by the existence of various defects. The whole field of fracture mechanics has developed in the last couple of decades in order to provide the engineer with tools to design his structures so as to avoid fracture in fatigue or corrosion fatigue conditions. In parallel, non-destructive testing techniques are being developed in order to characterise the defect distributions in materials, especially materials used in sensitive components in ships, pressure vessels, marine structures and aircraft. This defines a whole new area of new materials technologies requirements, namely, a means of monitoring the reliability of materials. In addition to suitable instrumental technical developments, there is a requirement for new modelling procedures, a new mathematical/statistical analytical understanding of fracture modes and means of designing structures against fracture. In high temperature turbine blades, in order to circumvent the common form of failure through the development of cracks along the grain boundaries, there have been new developments in superalloy turbine blades which are made from a single crystal - such are the materials objectives which are being defined by the functional needs of the engineering structure.

(v) Lighter, Energy Saving Materials

New technological constraints are being imposed on the transport sector, in particular by the need to save energy and to reduce the emission of polluting gases. This requires the introduction of engines with high thermodynamic efficiency, in reduced vehicle weight and improved frictional properties. Above all, in automobiles and aircraft of the future, there is a prime objective in increasing the strength to weight ratio of the materials used and therefore of lightening the structure and increasing its efficiency. Among the new light-weight materials, we include special steels, magnesium and titanium alloys as well as ceramics. Already advances are being made in introducing light weight materials in aircraft structures - for example, the structure of the Boeing 747 weighs about 100,000 kg and estimates indicate that it is possible to reduce this weight by a quarter through the use of advanced composites and light-weight metals. This will yield an annual savings, from a lower fuel cost alone, of a sum approaching one million dollars a year in the USA. In the case of the advanced Harrier, the AV-8B, 23% of the airframe is built in carbon fibre reinforced epoxy and the other materials are mainly aluminium and titanium. In the automobile of the future, it is envisaged that new plastics and composite materials will be progressively introduced over the next decade in parts such as the trim, the bonnet and boot-lid, the doors and various mechanical components. However, there is still much research required here: in particular, in deciding the optimum combination of matrix and fibres; in problems of compatibility and assembly technology; the effect of temperature, mechanical stress and ageing on fracture and strength properties of composites; development of non destructive testing procedures and automatic manufacturing methods; improvements in toughness and adhesion between the resin and the fibre and the role of water penetration; there is a need to devleop methods of joining heterogeneous substances and assembling and bonding them into final forms; there is a need for development of appropriate design methodologies involving complex load applications under fatigue, impact and energy absorbing

conditions; and furthermore, there is a need for the provision of suitable materials data in order to underpin all these studies. Again for transport innovations, there are developments in high strength aluminium alloys for applications in engine blocks, gear blocks, pistons and wheels and other special components. Here in particular, the aluminium/lithium series of alloys is showing promise. Such light-weight developments might have to be introduced in conjunction with new processing technologies, such a super-plastic forming, rapid solidification technology, developments in new casting methods (such as in semi-fluid paste or rheocasting). There are possibilities of introducing metal-matrix composites, such as aluminium reinforced by stronger fibres.

(vi) Specific Materials Requirements of Information Technology and Microelectronics

The onset of the revolution in information technology is familiar and needs no further elaboration. Whereas in 1959 the number of transistors on a semiconductor chip was 1, the increase over the last two decades has been of such enormous magnitude (with a logarithmic linear trend over the years), that in the future we expect to have 100 million tiny transistors on a single chip. This expected growth in complexity will be constrained by the availability of suitable materials, materials of greater perfection and new techniques for doping and for the conductors. In addition to this planar silicon technology, there are opportunities in newer, faster materials such as those provided by compounds of Group Three elements in the Periodic Table (gallium, aluminium, indium) with Group Five elements (antimony, arsenic, phosphorus) which offer enormous new potential properties for opto-electronic and microwave applications. In the field of Fibre Optics, the traditional electric current in copper for transmitting messages is being replaced by laser light moving in a tiny glass fibre. The power of this new technology is such that each fibre can transmit the equivalent of the complete Encyclopaedia Britannica in one minute! The research opportunities lie in improved fibres and better light carriers. By improving the absorption frequency of glass so that light of wavelengths approaching 3 microns can be transmitted, messages would be able to be transmitted for thousands of miles without having to employ repeaters, thus eliminating the main expense in long distance telecommunications systems.

In this particular important field, it is difficult to separate the precise materials requirements from the performance of the end product. A very extensive and complex technological infra-structure already exists in a number of countries and it is not prudent to enter this field in isolation from the manufactuirng and production of parts. This having been said, there are many opportunities in materials for micro-electronics applications, such as in wafer production (single crystal growing, slicing and polishing), other aspects of wafer processing, such as epitaxial growth, sputter techniques, oxidation and diffusion of impurities, ion implantation and in surface analysis techniques. In the future we will see systems with signals being processed at higher and higher speeds including cryogenic semi-conducting and Josephson - junction thin layer devices. These systems will require new electronic crystals, new thin film multiple layer materials and processing methods using photons electron beams, X-rays and other advanced processing methods.

5. In the above, we considered the future developments in terms of materials products (that is new materials, improved conventional materials) or materials technologies (processing techniques, laser surface treatments, protective coatings, near-net shape processing): through this procedure, we focus onto well defined R&D objectives in materials determined by engineering requirements.

However, the crucial pre-requisite for a planned system of research aimed to develop new materials is the presence of the scientific and often sophisticated technological infra-structure as well as the industrial basis that will provide the stimulus and financial support for such R&D. In considering Commonwealth countries with widely varying levels and maturity of industrial development, co-operative R&D networks which are highly specific to this situation must be evolved. This introduces the element of a lead nation, which would undertake the major programme planning and formulation, closely linked to the appropriately developed industrial infra-structure, with the less developed countries joining in on the basis of enlightened guidance and tutelage. This approach is probably unrealistic.

6. Generic Materials Developments Areas

Below we submit another procedure which is more equitable and in which all participating countries may contribute to a similar extent. This approach is through the underlying scientific and technological disciplines required for new materials developments. These disciplines are widely based, interactive, fundamental, with a strong technology content - physics, chemistry, metallurgy, ceramic science, polymer science, vacuum engineering, electron beam technology, laser beam technology etc. Hence the nucleus of any proposed collaborative R&D can be more fruitfully conceived in terms of a methodology based on a mix of basic disciplines. We select a number of generic subject matters - these will spawn the materials developments through the fundamental understanding of the primitive building blocks of materials - their nature, how they are assembled and their response to stress, temperature and environment. In both the developed and developing Commonwealth countries, there is above all a wealth of mathematical and basic scientific capability even in countries which lack the sophisticated R&D equipment. Thus mathematics and probability analysis is a foundation of fracture theories, in mechanical engineering design and in modelling. Any proposed structures for multilateral R&D involving the development of new materials should have as a basis a firm theoretical understanding, leading to the production of models, predictive analysis and design methods. In addition, the aspects of computer aided design and software should be closely interweaved in the programmes.

Below we offer some subject areas which depend upon a commonality of disciplines - generic subject areas which will have an impact on new engineering materials as well as the production of raw materials.

(i) Capillarity Phenomena

Although capillarity theory was developed in the 19th century and expressed in the work of Gibbs and other workers, there is still a considerable potential for development, both theoretically and in new applications to different systems and circumstances. This

involves a mix of mathematical analysis, surface tension analysis, organic and inorganic surface chemistry, surfactants and detergency theory. Some of the potential applications of interest to Commonwealth countries should be:

- in microporous media containing hydrocarbons: as much as 30% of hydrocarbons are normally left behind locked in the microporous strata in beds following normal oil recovery or extraction. Study of microcapillarity processes in such media, in conjunction with the development of suitable surfactants could lead to an increase in the recovery rate of hydrocarbons and reduce an otherwise enormous wasted wealth,

- the exploration of the use of surfactants to reduce the rate of evaporation from water reservoirs,

- the study of the role of surfactants in the flotation of mineral ores and the development of agents to improve flotation and mineral recovery rates,

- study of convectional behaviour in high temperature metallurgical and slag systems in pursuit of improved primary metallurgical refining efficiency,

- study of crystallisation and single crystal growth, for example single crystal superalloy turbine blades.

(ii) Joining Technologies

All engineering structures are as strong as the strength of the weakest bond - hence the all pervasive importance of sound joining procedures. This subject area requires further study in trying to understand the process of basic molecular cohesion and metallic bonding and the theory of adhesion between metals and organic substances. The strength of interfaces in all material systems is a constantly recurring theme, whether this is in embrittled steels or in the reliability of fibre-reinforced metal-matrix as well as organic-matrix composite materials. Specific effort might involve:

- study of solderability and other joining techniques in printed circuit boards, the basis of micro-electronic device technology,

- development in new bonding techniques appropriate to automatic manufacturing, such as diffusion bonding or friction welding,

- adhesive bonding of dis-similar engineering materials: nature of the adhered surface (here there are strong disciplinary connections with item (i) above).

(iii) Surface Engineering

This is a rapidly developing field in which solid surfaces are designed and engineered in order to withstand certain conditions of temperature and environment and to improve wear and frictional behaviour. It is rapidly becoming oriented towards sophisticated equipment, involving ion beam and electron beam technology, vacuum physics, vapour deposition and coating techniques as well as atomic scale surface chemical analysis. These methods are central to developments in materials for electronic devices. Studies that may be suggested here are

- ion implantation for improved corrosion and wear resistance,

- improved surface coating techniques, involving organic and inorganic films.

(iv) Electrochemistry

Again this is a convential field involving a mix of physics, chemistry and metallurgy but with enormous potential in future materials developments. Specific studies might include

- the electrochemical theory of aqueous corrosion of metals, including the role of corrosion inhibitors, stress corrosion cracking and corrosion fatigue (improvements in this area are vital to marine technology as well as transport of gas in pipe lines),

- electrode reactions: metal recovery by electro-metallurgy, such as improved aluminium refining techniques,

- developments in the storage of electricity and materials for batteries suitable for electric transport vehicles.

(v) Solid/Gas Reactivity

The manner by which solids, either in planar or particulate form, react with a gas phase is central to many aspects of materials innovation and processing. It is important in the integrity of materials used in advanced coal combustion plants involving the oxidation and sulphidation of high temperature materials used in power generation. Some possible lines of approach here might be:

- study of basic mechanisms of oxidation and sulphidation in high temperature materials with view to the development of adequate protective coatings,

- high temperature sintering reaction bonding of metal oxides, nitrides and carbides; the role of sintering additives (pressure sintering and pressure-less sintering).

We note that the technologies associated with the manufacture and processing of metal compound particles is central to the development of new ceramic materials having low porosity, low defect density and hence high strength. The future rewards in the application of structural ceramics to engineering bodies will lie not so much in the development of new ceramic chemical formulations, but in the development of suitable processing techniques, involving fine particles of uniform size, pure material stock and means of high temperature consolidation of the mass in order to achieve a defect free solid.

(vi) Fracture and Reliability Theory of Solids

These developments are central to the reliability of structures used in mechanical engineering: structures such as storage tanks, pressure vessels, ships and bridges. Further work is required along the lines:

- fracture reliability theory associated with defect populations,

- materials design to avoid fracture,

- mineral comminution theory: improvements in mineral recovery; the role of surfactants:

- study of fracture modes and debonding of composite materials.

Genetic Resources - Crop Plants

Professor N W Simmonds
Edinburgh School of Agriculture

1. I am asked to write a short paper on 'Genetic Resources - Crop Plants' in the light of the CSC's plans outlined in papers received; from these papers I note that genetic engineering and biotechnology are mentioned as (presumably) related issues.

2. I am an applied geneticist/plant breeder and have long experience of tropical agriculture in general, especially of certain plantation crops. I have been much involved also in genetic resource conservation work at the international level but can claim to be no more than moderately knowledgeable about biotechnology/genetic engineering.

3. On genetic resource conservation (GRC) of crop plants, the need is generally agreed to be acute because genetic erosion proceeds apace and serious GRC work is yet little developed outside the Consultative Group (CG) system of International Agricultural Research Centres (IARC). However, there is a body, one of the CG system, the International Board for Plant Genetic Resources (IBPGR), which is charged by the CG to promote GRC work globally. It does so, in my opinion effectively, though within the limits of constrained resources. The distribution of crop plant variability does not observe political boundaries and GRC efforts must (I think) be international. This being so, I can see no specific place for a generalised CSC effort in the area. Any funds available would, I think, be best spent through the IBPGR which already has well-established training-information networks in all the continents.

4. Further information would be available from the Executive Secretary, IBPGR Secretariat, FAO via delle Terme d Caracalla, Rome 00100, Italy. I cannot judge what effect recent FAO resolutions on genetic resources will have on the work of the IBPGR. There is a politically-motivated move afoot to bring IBPGR directly under the control of FAO. The Executive Secretary would no doubt advise you on that subject.

5. Important collections of four of the great plantation crops are held as follows: Rubber Research Institute of Malaysia (rubber), Palm Oil Research Institute of Malaysia (oil palm), West Indies Central Sugarcane Breeding Station (WICSCBS), Barbados (cane) and Banana Company of Jamaica (bananas). There is also an important sugarcane collection (of long standing) at Coimbatore. The Malaysian and Indian institutes are pretty well founded and do excellent work. The Jamaica banana work is in decline but there is reasonable hope of international support for it.

6. The WICSCBS, Barbados, does excellent work on very little money and has been the centre of a very effective cane-breeding network for the West Indies for over 20 years (much of the most effective scientific network that I know of in the area). Members are Guyana, Trinidad, Barbados, St Kitts, Jamaica, and Central Romana (Dominican Republic), with collaborators elsewhere (eg Panama, French Antilles). Staff are all local, the programme is cheap but imaginative and the quality of work well above ordinary for

tropical agricultural research. Internationally, it is very well regarded. Because of the weakness of the sugar industry, funds are short and the programme may collapse, at a time when the attractiveness of cane and cane products as sources of fibre, energy and chemicals other than sugar is just becoming understood. (For example, excess bagasse can be burned to generate power for the local grid). Very modest support would ensure the continuance of this excellent little programme, with implications not only for the cash economy of the islands but for the industrial scene as well.

7. I am surprised that none of the agricultural research bodies listed above (para 5) appear in the CSC project list and that Barbados, Trinidad and Guyana have no entries in the 'country-field matrix'.

8. On genetic engineering-biotechnology, I think one needs to be careful with the terminology (see Simmonds, Tropical Agriculture, Trinidad, 60, 66-69, 1983). I take genetic engineering to be the manipulation and wide transfer of specific DNA sequences, very high technology indeed and well on the way to revolutionising pharmaceuticals (and maybe some other products too, such as industrial enzymes). But it is yet irrelevant to plant breeding (despite extravagant hopes/claims) and is likely to remain so for years. What agriculture everywhere needs is straight, conventional plant breeding and lots of it; roughly 50% of agricultural advance is due to plant breeding. Hence my advocacy above of seizing on a good job of breeding that is actually working well, though in financial difficulties.

9. Biotechnology is a vague term that covers diverse in vitro manipulations of plant cells and organs (also by analogy, ovule explants and cloning, even Artificial Insemination (AI) work in domestic animals). In crops, in vitro techniques have been used for decades and are developing fast. The most valuable, so far, is in vitro growth of meristems of perennial plants for: (1) rapid clonal multiplication; (2) virus freedom; (3) genetic resource conservation; (4) international transmission of clonal stocks. Many laboratories are using the technique (pioneered) for sugar-cane by the WICSCBS, Barbados) but problems remain in some plants (especially trees). The IBPGR and the IARCs are much involved and several of the latter have long been using such techniques on herbaceous clonal crops such as cassava, yams and sweet potatoes. In the not-so-long run, I think, the method will become universal for genetic storage and clonal transmission.

10. It is only now, very belatedly, becoming understood that tropical agricultural research has grossly neglected the tree food crops (in favour of annuals), that these plants (eg breadfruit, avocado, pechibaye) are far from universally distributed, that they are of great socio-nutritional importance (especially in the wet tropics) and that they are deserving of far greater effort than they have yet had (see Watson, Exp. Agric, 19, 311-32 (1983). The international agencies (CG, World Bank, United States Agency for International Development, International Development Research Centre), etc) are taking note and one hopes for action in a very neglected area. Perhaps the CSC should consider it, as outline in para (11).

11. The fundamental requirements are simple: exploit in vitro meristems to spread numerous clones of numerous tree crops around the tropics. This sounds pretty pedestrian, low technology and so it is; but it is a fundamental preliminary to exploiting those plants fully for the human

good. Merely to get a lot of tree crops, in diverse varieties, established in a lot of places would be a really valuable achievement. Some 'enabling' research on how to manage meristems of particular species *in vitro* would probably be necessary. If the idea were to be developed, liaison with the International Council for Research in Agroforestry (ICRAF), Nairobi, Kenya, could be valuable.

12. I am willing to elaborate on these observations if the CSC wishes.

GENETIC RESOURCES

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"We are entering an age in which genetic wealth, especially in tropical areas such as rainforests, until now a relatively inaccessible trust fund, is becoming a currency with high immediate value."

Professor William Brill, University of Wisconsin

"Insofar as a species is no longer to be viewed as just a distinctive conglomerate of genes, but a multi-faceted depository of genes with distinctive attributes, the phenomenon of extinction takes on fresh significance. The loss of a single species does not simply mean the loss of one volume from the library of nature. It means the loss of a loose-leaf book whose individual pages, whether species to survive, would remain available in perpetuity for selective transfer and improvement of other species."

Professor Thomas Eisner, Cornell University

GENETIC RESOURCES

Genetic resources present many problems and opportunities for Commonwealth countries. They constitute an exceptionally valuable stock of natural resources, that are increasingly subject to irreversible depletion. Were Commonwealth countries to confront the challenge of genetic resources, they could undertake, notably in the form of research, training and information exchange, that would surely yield handsome payoffs for all parties concerned.

This paper starts off by summarizing the value of genetic resources, especially as concerns their economic applications for agriculture, medicine and industry. It goes on to consider how fast wild gene reservoirs are declining. It then proceeds to look at areas for cooperation among Commonwealth countries.

Distribution of Genetic Resources

The Earth's stock of 5-10 million species constitutes an abundant and diverse reservoir of genetic materials. The sum of genetic resources is much greater than is suggested by the number of species of plants and animals. A species generally comprises a good deal of "genetic spread", manifested through different sub-species and races, also populations, distinct in themselves while

genetically related to each other. The breadth of genetic variability inherent in a species is demonstrated by the many types of dog which man has developed, until we now have the St. Bernard and the Pekinese, the waddling Basset and the greyhound. These dog races, however differentiated they may outwardly appear, are much closer to one another in genetic senses than is the sparrow to the robin. We can discern similar genetic variation within different forms of cattle, as for other species of domestic livestock--and the same for maize and rice, among staple crop plants.

For reasons of evolution, the great concentration of species, as of genetic resources, occurs in the tropics--a zone that, with year-round warms and often with year-round moisture, fosters evolutionary processes and proliferation of species. This relatively small sector of the Earth's surface harbours at least two-thirds of all species; and their genetic variability often turns out to be greater than is the case with non-tropical species. The richest zone of all is the tropical forest biome, which, amounting to 10 million square kilometres at most, comprises two-thirds of all tropical species.

More than we might suppose, wild species and their gene pools serve our welfare at dozens of points in our daily round (Myers, 1983 and 1984; Oldfield, 1981). Not only do they supply natural products such as timber and rubber, but they provide germplasm, or living tissue that harbours hereditary codes in the form of genes. It is these germplasm resources that enable human communities, through techniques of plant breeding and bio-engineering, to devise

improved forms of established products, together with entirely new products, in leading economic sectors such as agriculture, medicine and industry. By contrast, temperate zones are relatively deficient in species concentrations and gene reservoirs. Yet it is the developed countries, situated largely in the temperate zones, that possess most technological capacity to exploit species and their genetic resources for economic advantage--a situation that raises several issues salient to North-South relations (Myers, 1981). While many Third World leaders recognize the values of wildlife, they often do not possess the funds and scientific skills among other conservation perquisites to do a sufficient job of safeguarding their threatened species.

Economic Applications of Genetic Resources

Let us take a quick look at some of the utilitarian benefits we derive from species and their genetic resources.

1. Agriculture

The productivity of our major agricultural crops cannot be maintained, let alone expanded, without a constant infusion of fresh genetic variability (Frankel and Bennett, 1976; Frankel and Soule, 1981). Much of this genetic material comes from wild plants, the relatives of modern corps. Indeed, the skils of plant geneticists, even more than the use of artificial additives such as fertilizers and pesticides, have yielded one record crop after another in North America. Of course it is difficult to separate the contributions of

genetic materials from other factors that enable certain crop variants to flourish. But as a rule of thumb--an exceptionally tough rule of thumb--agriculturalists estimate that, across the board, we can attribute some 40 percent of expanded productivity to genetic breeding, and hence to the germplasm and other genetic materials on which crop breeders depend. Put another way, we can estimate that genetic improvements account for at least one percent of agricultural productivity overall each year--an annual increment that, in the United States, is worth about $1 billion.

In addition to these genetically-derived improvements of existing crops, wild species offer much potential for entirely new foods (National Academy of Sciences, 1975; Office of Technology Assessment, 1981). The Earth contains some 80,000 edible plants, of which man has, at one time or another, used at least 3000 for food. Yet only about 150 have ever been cultivated on a large scale, and less than 20 produce 90 percent of the world's food. We are essentially using the same limited number of plant species as have served humankind for centuries.

Examples abound of under-exploited food plants with proven potential. A wild Australian grass, Echinochloa turnerana, yields nutritious grain with just one deep watering, and thus offers important scope for dry-land farming in areas with sporadic rainfall. An acacia tree (A. albida) occurs in savannahs of East and West

Africa, being a leguminous tree that maintains verdant foliage and fruit during the dry season, when its leaves and pods, relished by all kinds of livestock, often prove to be the only fodder available at that stage of the year. Cocoyams (Xanthosoma spp.) are highly productive root crops that are more nutritious than cassava, and quite readily grown; although widely cultivated in e.g. Nigeria, Ghana and Sierra Leone, they have never been subjected to a comprehensive improvement programme, and they appear to have much unrealized potential. The wax gourd (Benincasa hispida), grown in the Indian sub-continent among other parts of the Asian tropics, is a large melon-like vegetable, easy to grow and yielding three crops a year; its fruit can be kept without refrigeration for as long as twelve months--a distinct advantage in tropical countries. The durian is a large, spiny fruit of Malaysia and other parts of Southeast Asia, esteemed for its taste; while the mangosteen, also of Southeast Asia, ranks as possibly the world's best-tasting fruit.

So much for a brief illustrative selection of a cereal, a forage crop, a root crop, a vegetable, and a couple of fruits, all of which appear to offer much scope for future exploitation. At least 600 further new foods have been documented, as worthy of urgent development. The great majority of them occur in the tropics, especially in the humid tropics, and notably in such Commonwealth countries as Malaysia, India, Kenya, Nigeria, and certain countries of the Caribbean. As an example of what can be accomplished, let us

note the recent story of the winged bean (Psophocarpus tetragonolobus), a climbing bean that has traditionally been important in Southeast Asia while remaining unknown elsewhere. Through collaborative endeavour on the part of geneticists, plant breeders and agronomists of the U.S. Agency for International Development, together with the half-dozen countries of origin in Southeast Asia, the winged bean has now been developed into a protein-rich crop that helps to enhance diets in several dozen countries of the humid tropics, where it could eventually serve as a counterpart of the soyabean. Similar breakthroughs could lie ahead for many other little-known and under-exploited tropical plants with promising economic value, were a systematic effort to be mounted to make them more widely known.

2. Medicine

Wild plants contribute an array of startpoint materials for many modern drugs and pharmaceuticals (Myers, 1983 and 1984; UNESCO, 1981). Indeed one in four of products sold in modern pharmacies owe their origin, in one way or another, to wild plants. The commercial value of these products has now reached the equivalent of some $10 billion a year worldwide. In 1960, a child suffering from leukaemia had only one chance in five of remission. Now, thanks to drugs prepared from a tropical forest plant, the rosy periwinkle, originally native to Madagascar and now proliferating in the West Indies and other parts of the tropics, the child enjoys four chances in five. Commercial sales of the materials for anti-cancer drugs derived from this one plant currently total around $100 million a year. According to the U.S. Economic Botany Laboratory, tropical rainforests may well harbour at least half a dozen plants that contain

ingredients for other anti-cancer drugs. In addition to tropical forests, other tropical zones harbour much promise, for example coral reefs, which abound with organisms producing medicinal materials, for example a Caribbean sponge with anti-viral agents that are effective against herpes encephalitis, a deadly brain infection.

As with agriculture, there is surely massive scope for exploitation of wild sources of medicinal materials. What is principally needed, in the first place, is a methodical research effort to assess the potential. Again, too, the richest genetic reservoirs occur in the tropics, while the main capacity to develop them, in terms of scientific and technical skills, lies with developed nations.

3. Industry

Herewith a short illustrative selection of plants that assist modern industry. Guar (Cyamopfas petragonoloba) is a leguminous herb that is currently grown in semi-arid areas of Pakistan, India and Australia. Its high-protein seeds contain a gum that is in increasing demand by industry. Because of its unusual properties, the gum has many uses, from making water slide more readily through fire hoses to thickening for icecream and other dessert foods, also as a key component in paper making. Ramie (Boehmeria nivea), now grown in Malaysia and other parts of Southeast and East Asia, is a tall perennial shrub that produces a fibre with superior qualities, notably

strength and freedom from stretch and shrinkage. A host of other plants of the tropics produce lubricating oils and waxes, gums and exudates, essential oils, resins and oleoresins, dyes, tannins, vegetable fats, and multitudes of other biodynamic compounds. We benefit from these plant materials each time we wash our clothes, use a sunscreen lotion, paint a wall, varnish the table or our fingernails, hit a golfball or pull on our jogging shoes, mail a letter or use drilling muds.

Still more to the point, the chemical industry, worth $300 billion a year worldwide, continues to derive most of its raw materials from fossil petroleum, obtaining a mere 3 percent of its needs from alternative sources such as vegetable fats and oils. But during the past 10 years, the cost of petrochemicals has increased seven times over, and their price appears likely to increase steadily until many products are priced beyond the reach of the consumer. Fortunately almost all petrochemicals can be replaced by phytochemicals, of which the greatest variety exists in the tropics.

So much, then, for a brief review of some economic applications of wild plants. Yet despite the many thousands of products already available, scientists have conducted a cursory screening of only one plant species in 10, and intensive screening of only one plant species in 100. If researchers were to undertake a comprehensive and systematic analysis of all 250,000 plant species, it is certain they

would uncover vast numbers of new materials to enhance our daily welfare. Indeed the discoveries already made suggest we should regard the world's wild plants as a uniquely valuable stock of raw materials--possibly the most diversified and abundant stock of natural resources on Earth.

Extinction Rates

Regrettably the Earth's stock of species is being depleted at ever-more rapid rates (Myers, 1979). We are now losing at least one species each day, and by the year 2000 we could lose one million, while by the middle of the next century we could lose one third of all species. These extinctions are almost entirely due to loss of habitat and disruption of life-support systems, almost entirely due, in turn, to activities on the part of humans that are unwittingly destructive of natural environments and their species communities. Nor is the loss of species the whole story. Many surviving species, not so depleted as to qualify for threatened status, may well have lost 90 percent of their populations, which means they may well have lost half of their genetic diversity.

Clearly we need a greatly expanded effort to safeguard wild species. In light of their genetic resources and their many economic applications, there should now be enhanced incentive for the scientific community, supported by political leaders, to address this

great "sleeper issue" of disappearing species and declining genetic reservoirs.

Rationale for Collaboration

As we have seen, many genetic reservoirs are confined to a small part of the Earth, primarily the tropics. Of course certain gene pools occur outside the tropics. Those of wheat, for example, are limited, for the most part, to Turkey and the former "Fertile Crescent", while the native homes of maize are found in Central America and northern South America--not in Commonwealth countries. Sufficient gene reservoirs occur in Commonwealth countries, however, for the whole issue to merit the urgent attention of CSC.

The localized distributions of many genetic reservoirs places a premium on cooperation. Obviously many nations can benefit from the genetic endowment of just a single nation or a handful of nations. This argues that all beneficiary nations should find it in their economic self-interest to share in scientific exploration of genetic stocks wherever they exist; and they should contribute to research-and-development efforts. This collaboration deserves to be matched by institutional initiatives to ensure that information is shared on a broad basis. Here lies a major opportunity for the CSC.

Because much scientific expertise and technical skills lie with nations of the North, whereas genetic stocks occur mostly in nations

of the South, there is an obvious opening for joint efforts on the part of both North and South nations. This applies especially to genetic stocks that serve the needs of nations of the North as well as those of the South. These considerations are all the more relevant in light of the emergent industry of bio-engineering, provided it can draw on sufficient variability of gene pools in the wild, bio-engineering may shortly transform the genetic underpinnings of leading economic sectors. For example, there is prospect that genetic engineers may eventually be able to adapt the genetic system of leguminous plants that enables them to "fix" free nitrogen from the atmosphere, thus supplying their own fertilizer. Were scientists to introduce a self-fertilizing capacity, through incorporation of nitrogen-fixing genes, into major crop plants, they would reduce the need for chemical nitrogen fertilizer that now costs the world's farmers some $15 billion a year--a salient advance that would assist developed-world and developing-world farmers alike.

As for South-South collaboration, an illustrative example lies with the rubber industry in Malaysia. The original species of rubber trees from Amazonia, of which 26 seedlings eventually reached maturity in Malaysia (an extraordinarily narrow genetic base on which to build the present plantations with their many millions of trees), retain a range of related strains and ecotypes in the wild. The samples originally collected more than 100 years ago certainly did not include the best variations, either for quantity or for quality of rubber output. Nine additional additional species of the same Hevea genus

offer other valuable characteristics such as disease resistance. More important still, the Amazonian habitats where rubber originated feature a potent fungal parasite known as South American leaf blight. Were the disease ever to make its way, through accident, to Southeast Asia, the blight could cripple the natural rubber industry within just a few seasons. Fortunately a number of wild species of the Hevea genus offer resistance to the blight--just as others offer resistance to other diseases, and still others offer tolerance to cold, or to too much or too little moisture. Hence Malaysia's rubber industry is critically dependent on wild gene reservoirs in Amazonia.

Similarly, cocoa growers of Ghana and other countries of West Africa rely in part on wild genetic reservoirs in Amazonia, and in relict patches of forest in the Pacific coast zone of Ecuador--where one particular variety of the cocoa plant has now been reduced to just a few surviving individuals in the 1.8-square kilometre Biological Reserve at Rio Palenque. This is a type of cocoa with better taste and other virtues than occur in almost all other gene pools of wild cocoa.

Similarly again, sugarcane growers in the Caribbean are threatened by a mosaic virus transmitted by aphids. Fortunately mosaic-tolerant varieties of sugarcane are found in a wild species that grows in forests of Southeast Asia. Still further wild types of sugarcane supply resistance to red rot, gommosis and other pathogens that trouble sugarcane growers.

Scope for Action

We can consider opportunities for action initiatives on the part of CSC under three main headings, viz. research, training, and information sharing.

1. Research

Despite the apparent relevance of genetic resources to our material welfare, both for the immediate and long-term future, we have conducted all too little research. In fact we have only a hazy idea of plant species that exist in the wild--how many they are, how widely (or narrowly) they are distributed, how well (or poorly) they survive, what their main economic contributions could be, and so forth. Great Britain possesses more botanists and taxonomists than there are plant species in the country, around 1800. Of tropical nations, only India has prepared a methodical listing of its flora, some 8000 species. In scientific and economic terms, this surely represents a maldistribution of scientific support. Similarly, Canada, relatively poor in plant species, possesses many times more plant researchers than Malaysia, which harbours almost half as many plant species as the whole of North America. We can make similar comments about Australia, vis-à-vis Kenya, and so forth.

Having identified plant species in the wild, we need to document their "vital statistics", viz. their range, their genetic

variability, their conservation status and the like. Strange as it may sound, we possess only a rudimentary knowledge about the wild relatives of our staple crop plants, unusually valuable though they are. For instance, rice: a few years ago, a leading hybrid cultivar of Green Revolution rice, IR-20, was hit by grassy stunt virus, a disease spread by brown hopper insects. So potent was this threat that it could have proved devastating for the huge numbers of people in Asia who depend on rice as their staple food. Rice geneticists examined rice gene collections around the world, totalling some 47,000 items, searching for resistance to the disease--but to no avail. So they turned to wild relatives. Fortunately they came across a single wild species in Kerala in the southern part of India, allowing them to transfer the appropriate genes to established rice varieties. Despite the fact that the situation was saved through this wild Indian relative of rice, little survey work or inventorying is being undertaken to determine the location and relevance of other wild rices. A relatively small investment in research of this sort would surely yield a sizeable payoff. The economic benefits from genetically improved rice in Asia during the 1970s are estimated to amount to some $750 million.

Parallel research needs to be conducted into little-known and entirely new foods, with scope for success stories along the lines of the winged bean.

2. Training

While the developed nations of the North can assist with basic research efforts, there is an urgent need for developing nations of the South to develop their own skilled manpower resources, especially as concerns indigenous technology. Because of misplaced priorities in national development programmes, there is a dearth of institutional resources to adopt and adapt the technological means to build up "home grown" capacities. Just as developing nations are severely handicapped through lack of basic scientific skills (as indicated under 1. above), so there is a critical shortage of training infrastructure.

Again, this presents opportunity for a "pump priming" initiative on the part of the better-placed nations of the North. Through a comparatively limited input of experience and expertise, the nations of the North can stimulate the establishment and growth of training centres and similar institutional networks in nations of the South. Nations of the North obviously possess a reservoir of established talent in this area. What is required is, first, a recognition of the problem in the South, followed by back-up support from the North. A collaborative programme should not be difficult to establish, it need not cost much in the way of institutional resources, and the payoff could be exceptional in terms of the catalytic effect. There is not scope in this limited paper to list the specific measures necessary; rather the paper identifies the problem and the opportunities at issue.

3. Information Exchange

Needs and initiatives can be illustrated under this heading through the field of medicine. In several Commonwealth countries of the tropics, such as Ghana, Zimbabwe and India, a number of research organizations have recently been established, to assess the potential for plant-derived drugs and pharmaceuticals. These research organizations have achieved some pioneering breakthroughs, especially in the way of "green medicine" that must meet the health needs of developing nations for the foreseeable future (on the grounds that they will not be able to afford Western-style medicine for decades to come). It is surprising and regrettable, then, that there is not more collaboration, on systematized basis, between these research centres. Again, this situation offers opportunity for collaborative initiative on the part of the CSC. Through only minor investment of scientific skills and the like, a substantial return could be achieved in terms of information transfer and dissemination.

On-Going Activities Among Other Agencies

As indicated, the problems associated with genetic resources are great. We know all too little about the nature and extent of gene reservoirs in the wild: this is a prime gap in our knowledge. At the same time, we do know that there is a process of "genetic erosion" under way: while little recognized by political leaders and policy makers, there is a consensus among scientists and conservationists to

the effect that we face a phenomenon of mass extinctions during the course of the next half century or so. Fortunately this extinction spasm is only starting to get under way, and there is still time--if we can mobilize the key components of basic awareness, accompanied by political commitment--to stem the tide of genetic erosion.

Hence there is need for a "consciousness raising" exercise on broad scale. Among agencies involved with this issue of resource depletion are, first and foremost, the International Union for Conservation of Nature and Natural Resources, in association with the World Wildlife Fund; also Oxfam. These NGO efforts are slowly but steadily being matched by initiatives on the part of official development agencies such as the U.S. Agency for International Development, which has been mandated by the U.S. Congress to pay greater attention to biological diversity in general, and genetic resources in particular; by the International Board for Plant Genetic Resources under FAO; the Consultative Group on International Agricultural Research under the World Bank; and by subsidiary measures on the part of UNESCO and UNEP. Thus an expanded programme on the part of the Commonwealth Science Council will need to be co-ordinated with on-going activities on the part of other agencies involved.

So tentative are these initial efforts on the part of other agencies, however, that a contribution on the part of the Commonwealth

Science Council will certainly be welcome: it will not be an effort in isolation. All the more, then, a relatively limited-scale initiative on the part of CSC would serve to support and enhance the preliminary work already underway.

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AGRICULTURE

(Excerpts from a communication from Sir Charles Pereira)

The "Chairman II" Conference in Manilla some 18 months ago explored the opportunities open to chemistry and biochemistry to promote the agriculture of developing countries. I chaired the crop production symposium and took part subsequently in a scientifically strong "Future Actions Committee" to summarise the outcome of the Conference. I attach a summary of the relevant recommendations of that Committee, which should, I believe, provide a useful input to your Committee's discussions.

I would urge you, however, to consider the degree to which agricultural practice in the developing countries is currently suffering, throughout the tropical world, from the concentration by agricultural scientists on academic studies. By enlargement of opportunities to pursue scientific careers in the air conditioned urban centres, the gulf between the way of life of the agricultural scientist and the peasant farmer has been growing, in my personal observations, with increasing momentum over the past 3 decades. I have spent the past five years in almost non-stop travelling, leading or taking part in many missions on agriculture, forestry and agricultural research in South and South East Asia, Southern and Eastern Africa and South America. The general picture thus observed is of a population explosion of subsistence farming communities, receiving very little help from their scientific fellow-countrymen except where this is part of an external aid effort organised by donors. These latter efforts collapse routinely when overseas influence is withdrawn because, with honourable exceptions, "Third-world" scientists will not live in rural areas.

Adaptation of agricultural technology requires skilled field testing in genuine farm conditions. Where problems arise this must be followed by competent on-site investigation of soil, climate, plant material and plant protection variables. This cannot be done from the university campus in the city. Therefore over the vast range of tropical subsistence agriculture it is not being done.

I do not doubt that the Commonwealth Science Council is usefully improving university science overseas. Having spent last month in Southern Africa, I am acutely aware that populations are already over-running food supplies and that the agricultural academics are "fiddling while Rome burns". Perhaps they should award higher degrees for getting technology used!

I do not think that this applies to other fields of science which your Committee will be covering, but on present information, unless the food and fuelwood races against time are won, the other sciences will be somewhat irrelevant in many developing countries.

With best wishes for the work of your Committee.

"CHEMRAWN"

Early in the year 2015, if present projections prove to be valid, 8 billion people will be living in the world. In the very short span of 40 years since 1975, population will have doubled from 4 billion. The implications are formidable:

> Farmers and livestock keepers will have to increase annual food production by an amount equal to the annual level that they have reached in the 12,000 years since man first introduced domesticated animals and farming.

Recommendations. In order for the recommendations that follow to be carried out, governments of tropical developing countries must:

* Give priority to controlling land use on watersheds to reduce soil erosion and flood damage.

* Improve support they give to farmers on the better soils and control the expansion of agriculture onto unsuitable land.

* Ensure that the ratio of prices for crops to prices for fertilizers provide profits to farmers.

* Deploy farm technologists from urban to rural areas.

Based on the foregoing summary and on the suggested government actions, we recpomend that:

> Multidisciplinary field studies be conducted throughout tropical and subtropical developing countries to find the limiting factors between present yields and the maximum yields possible under laboratory conditions and the results widely disseminated in relevant rural areas.

> New, more effective, and less costly formulations of slow-release and pelleted fertilizers be developed and made available to farmers in tropical developing countries.

Increased studies be made of local sources of phosphate rocks in tropical countries with a view to developing simpler methods of processing and use.

Much greater support be provided for long-range studies to develop processes that are significantly less costly for fixing nitrogen, including direct oxidation processes as well as processes for producing hydrogen from water using solar radiation as the source of energy.

Pest Management

Presently available knowledge of pest control systems be widely disseminated and adapted to conditions and practices in developing countries as rapidly as possible.

Development of new pest control chemicals and new biological control methods be assigned high priority not only for major crops in developed countries but especially for crops that are important in developing countries but that are not economically important targets for research in developed countries.

Internationally-accepted standards of safety for people in different environments be established and international agreements be reached on registration, licensing, and patent procedures for pest control chemicals and methods.

Animal Production Systems

Research and development projects be given priority that (a) seek to maximize the biomass produced photosynthetically; (b) will tailor use of biomass elements in the most efficient manner for animal production and for other purposes, such as fuel, fibers, chemicals for organic syntheses, and products of fibrus raw materials; and (c) reduce pollution of the environment by gaseous, liquid, and solid wastes.

Research and development be multidisciplinary, so that crops, livestock, fish, biomass, and energy sources contribute most efficiently to totally integrated systems at levels that range

from individual farms to larger regions, with due regard for different cultural practices among regions.

Integrated animal disease control programmes be devised based on (a) new genetic types of animals bred for disease resistance; (b) continuous disease monitoring and appraisal systems for livestock diseases; (c) improved chemotherapeutic and prophylactic measures appropriate for large animal husbandry enterprises and also for small, individual farms; and (d) increased application of appropriate biotechnology to control infectious diseases and cancer.

Close attention be given to methods to control reproduction with hormones and hormone regulators affecting offspring sex and timing of ovulation and parturition, in order to allow genetic improvements to be achieved more rapidly and also to facilitate the development of animal management systems that are well integrated with particular cultural practices.

Food Processing

Increased emphasis be given to research and development programmes to improve preservation methods, especially those that can be operated at the home or small-community level without large infusions of capital but that produce foods that have good nutrition and that will be accepted in light of local customs and preferences.

New packaging materials be developed that will give adequate protection and shelf life to foods under tropical conditions.

Intensified efforts be made to gain an understanding of changes that foods undergo following harvest, so that more effective ways can be devised to retard spoilage and deter attack by micro-organisms, insects, and animals.

Persons seeking to improve specific crops by hybridization and genetic engineering rank postharvest storage and processing characteristics as high in importance as they rank yields, nutrition, and esthetic properties.

Research and development continue at about the present level on such recognized methods for enhancing food supplies as supplementation with amino acids and vitamins and preparation of food analogs based on single-cell proteins, regenerated protein foods resembling meat, and carbohydrates and fats derived from simpler chemicals.

The Forward Edge

Officials of public and private funding agencies, managers of research organizations, and agricultural scientists rate research in all aspects of plant physiology as worthy of the highest priority when securing funds and when apportioning funds among projects for support.

Officials, managers and scientists in developing countries especially recognize that research in plant physiology is not the exclusive domain of developed countries or of large industrial companies and therefore support such research, particularly on crops of importance to their countries that might otherwise be ignored or at least given much less emphasis by developed countries and by large industrial organizations.

Existing cultivars of various crops be screened to determine photosynthesis quantum conversion efficiency in projects in which institutions in developed and developing countries work together, with specially-trained specialists and the requisite highly-technical equipment from developed countries working on location with the cultivars collected and grown under normal conditions.

Improved legume cultivars and Rhizobium species be matched for enhanced nitrogen fixation and yield; improved Azolla-Anabaena symbiosis for paddy rice, mycorrhizal inocculants, and improved Rhizobium be developed to simplify inocculation; and ways be found to bring about a major increase in photosynthetate available to legume nodules, which provide a strong benefit analogous to the multifold increase in nitrogen fixation experimentally demonstrated by foliar carbon dioxide enrichment of field-grown soybean.

An expanded programme of scientific co-operation in the Commonwealth for agricultural science and production

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Introduction

This paper seeks to identify the contribution which the Commonwealth Science Council might usefully make in the fields of agricultural science and production over the next one to two decades to ensure that the agricultural and food industries of member states are better equipped to meet the challenge they will face in the early years of the next millenium. To attempt this requires us first to establish in outline the demands which will be placed on agriculture by the year 2000. Second, to speculate the long-term consequences of those changes now in evidence with respect to the availability and cost of the resources employed in agriculture, viz. land, labour, capital and management. Finally, we must pay due regard to the rapidly changing social and political framework, both national and international, within which the agricultural and food production industries must operate.

Only some of the more important factors are listed below:

(i) Annual growth rates of population in many Commonwealth countries are such that food production must be doubled within a time span of twenty to thirty years if hunger on a huge scale is to be avoided and scarce foreign exchange is to be used for purposes other than food importation.

In a minority of the industrialised Commonwealth states where populations are already static or growing only modestly the demands now in evidence for healthier diets and improved food quality will gain further momentum.

(ii) In general, increased agricultural production must be won from land already in cultivation. With the exception of a few Commonwealth states new land is either not available or it requires unacceptably high levels of investment (for clearance, infrastructural development, irrigation, drainage, soil conservation, etc.) to bring it into cultivation. Furthermore, we must

endeavour to obtain sufficient food without unnecessarily diminishing wild habitats which may come to have an increasing economic role through tourism.

(iii) The application of more intensive methods of agricultural production to more land will increase the likelihood of higher levels of environmental pollution through a period when people will be more educated and aware of the impact of such problems.

(iv) It must be assumed that fossil fuel energy resources will become increasingly scarce and expensive over the next two decades and that for some countries there will be very real risks of total disruption of supplies.

As fossil fuels become relatively more expensive, so too will those agricultural inputs, e.g. agrochemicals, field machinery and fixed equipment, etc. which depend upon them for manufacture.

(v) For most Commonwealth states, long-standing trends in which the percentage of the labour force engaged in agriculture is diminishing must be expected to continue. Unless prosperity and services (health, education, cultural, etc.) can be rapidly developed in rural areas, urban drift will continue apace, accelerated by the application of increasingly sophisticated methods of mass communication. There is a profound, latent dissatisfaction with the routine and drudgery of lifestyles associated with labour intensive methods of agricultural production in the context of small family farms. It takes little to trigger the desire to search for something different.

(vi) Future levels of capital investment in agriculture are unlikely to match needs but sadly, and of greater significance, there continues to be a shortfall in management resources capable of ensuring that that capital which is invested is productive.

(vii) Although outside of the scope of this paper political stability and law and order remain vital prerequisites of agricultural development and without them no amount of success in science and technology will ensure that people are adequately fed.

A general policy for the CSC

The human, physical and financial resources likely to become available to the CSC for agricultural and food research are modest. Accordingly, if the CSC is to make an impact, it must avoid the temptation to spread its efforts too thinly. It should endeavour to identify distinctive contributions which

derive from the uniqueness of the Commonwealth family of nations and its institutions. It is against this background that a few general policy guidelines are suggested

- The CSC is particularly well-placed to maintain and regularly up-date an inventory of national research programmes, to identify common science problems and to become pivotal in the transfer of knowledge and experience between member states. It should not engage directly in the development of research facilities for specific problem-solving activities.

- The CSC programme should concentrate on those areas of science which are most likely to further the production, storage and processing of food (both crop and animal derived) rather than non-food agricultural commodities. This is not to deny the importance of plantation agriculture and industrial crop production but acknowledges that this sector is broadly in a position to secure its research needs from within.

- It is suggested that CSC recognises the primacy of need for research which will better enable small farmers (say the 1-10 ha group) to improve their levels of productivity. To be effective such research should take into account the resource base of the small farmer which is often ill-understood by the scientific community.

- The CSC should, by the nature of its support, seek a better balance of research between that aimed at improving production efficiencies on-farm to raising the proportion of agricultural production which eventually enters the food market in either the processed or un-processed form. Much more must be done in the post-harvest sphere than has been the case, both for crop and livetock products. A somewhat different approach is called for, one which recognises that agriculture and food is a continuum and not two distinctive, albeit related, systems. Agricultural research must above all seek to enable dietary requirements and preferences to be met and thus this should be our start-point.

Science or technology ?

The brief provided for this paper made reference only to "agricultural science". It made no mention of "food" or "technology".

The magnitude of the food problem over the next twenty years will be such that we must not only advance our understanding of the biological systems which give rise to food but we must also improve our capacity to apply scientific knowledge in the service of mankind. Thus, in the field of agriculture and food production, science and technology must be regarded as inseparable - CSC programmes should be encouraged to embrace science, engineering and management. Indeed, CSC should make special endeavours to achieve effective integration within these three spheres.

Specific areas for research

In selecting specific areas of research for agricultural science and production for the CSC note is taken of the fact that synoptic papers have also been invited for a number of closely related fields, *viz.* genetic resources, integrated resource management and genetic engineering. Each of these is capable of making an immensely important contribution to natural resources development and food production. Perhaps as much as half of the crop yield advances which have been made in those countries where agriculture has been especially successful over the last generation or so is attributable to varietal improvement alone. Plant breeding, then, must continue to be a priority area for the CSC and so too livestock improvement programmes which seek to exploit more fully the science and practice of ova transplanting. No further reference will be made to genotype improvement in this paper, the assumption being that they will be dealt with more extensively elsewhere.

It is suggested that within agriculture and food the CSC operate in the context of a relatively small number of carefully selected, broadly based programmes which are periodically reviewed. Such reviews might be made at five yearly intervals to provide opportunities for termination, changes of direction, initiation of new programmes, etc.

The following programmes are put forward for consideration:

1. Agricultural commodity processing and storage

Justification: for both crop and livestock products, but particularly for crops, high losses occur during harvesting through to the point of consumption.

Problem areas: identification of the extent and causes of losses, including development of loss monitoring techniques. Storage environment requirements for perishable and durable commodities. Environmental control and process engineering. Packaging and materials handling.

Programme elements: collaborative research, technology development, training and information exchange but with emphasis on the three latter elements.

Potential benefits: considerable improvement in the utilisation of agricultural production over that currently being achieved.

2. Farming systems analysis, design and management

Justification: to improve production efficiencies,to identify the threat to and protection measures for sustaining the well-being of land and to better enable appropriate research and development priorities to be formulated.

Problem areas: the performance (output per person, output per hectare, etc.) and soil-degrading practices featured within some farming systems which threaten the long-term production potential of land. In particular need of research are fallow farming systems and those systems practising the continuous cultivation of short-term crops on rain-fed land where only small areas of land are available per family. But, other systems should also be included.

Potential benefits: a better understanding of the totality of farming systems and identification of the ways in which they might be more effectively planned and managed. Research priorities and prime targets for investment should emerge from such programmes of investigation.

3. Soil and water management

Justification: soil and water management problems are of a high order in many Commonwealth countries and are, in many situations, prime factors in explaining low yields and high production costs.

Problem areas: especial emphasis should be given to developing a better understanding of the physics and engineering of soils and soil water in the context of crop establishment, growth and yield. Key problems include tillage, soil erosion and

and conservation, soil-plant-water relationships, removal of excess water from soil and improving the efficiency of water use within irrigated agriculture.

Programme elements: collaborative research, training and information exchange.

Potential benefits: the development of more effective soil and water management techniques, manpower training, technology transfer.

4. Crop nutrition

Justification: crop nutrition is a major limiting factor to crop production in many parts of the Commonwealth.

Problem areas: fertility maintenance in those farming systems in which inorganic fertilizers are beyond the purchasing power of farmers or simply not available. Improvement in the recovery of nutrients from inorganic fertilizers is needed where they are used.

Programme elements: collaborative research which includes surveys of fertilizer practices, crop responses to applied nutrients and studies which clarify the role of crop rotations.

Potential benefits: more cost-effective crop nutrition policies which might be made by biological agencies.

5. Pest management

Justification: the development and application of techniques aimed at increasing yield will bring in its wake a need for better pest prevention and control measures.

Problem areas: pest forecasting techniques and fundamental studies which seek to determine costs and benefits of alternative control/prevention methods.

Programme elements: collaborative research, training and information exchange all have a role.

Potential benefits: more cost-effective, safer methods of prevention and control.

6. Genotype improvement

(This is the subject of another synoptic paper)

NOTES ON COMMONWEALTH SCIENCE COUNCIL

PROGRAMME ON AGRICULTURE

by

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GENERAL INTRODUCTION

The authors have taken into account the fact that Prof R Radley will also be commenting on the agricultural sector. They have therefore concentrated on providing a full discussion on post harvest work which is unlikely to be covered by Prof Radley and have called attention to a limited number of specific areas chosen by guidelines which are set out later in this introduction.

In many of the smaller Commonwealth (developing) countries scientific research has been directed towards solving problems of agricultural production. Yet in many instances an adverse balance of trade in agricultural products has become more common in recent years. In addition, the well documented need for increased food production in the developing countries, underscores the importance of continued scientific input in this sector. The International Institutes supported by CGIAR have made tremendous strides on particular crop species. However the impact of this work is very much dependent on the strength of national research and development institutions.

BIOTECHNOLOGY

Developing countries are naturally attracted to the potential applications of biotechnology in solving their manifold problems related to improving their people's Physical Quality of Life Index. A major application will be in agriculture and food production. Productivity improvement in agriculture can occur via a number of ways including increased yields.

I Biological Nitrogen Fixation

Legumes constitute an important element of both food and feed in every country supplying in many developing countries crucial protein needs of the population. Productivity improvement of leguminous crops will therefore be a significant element in the overall agricultural contribution to health, welfare and economy.

Biological nitrogen fixation is carried out by legumes and is mediated through the Rhizobium plant symbiotic relationship. Traditionally the plants have become infested naturally through Rhizobia already present in the soil. A number of countries now remove this element of chance inoculation by pre-inoculating seeds with the necessary Rhizobia before distribution to the farmers.

There are a number of constraints hampering the more widespread adoption of this technology in the tropics. One of these relate to the view that tropical legumes are promiscuous i.e. will nodulate with any of several strains of Rhizobia and that tropical soils are so laden with Rhizobia that effective nodulation must occur naturally.

This view reflects inadequate research with tropical legumes since the more these legumes are studied the more examples come to light of specificity between legumes and *Rhizobium* strains quite as pronounced as is the case with temperate legumes (Date & Halliday 1979, 1980).

The research being proposed is to expand the experiences of the *NifTAL* project to the Commonwealth countries to investigate specificity relationships between *Rhizobium* and legumes and whether pre-inoculation of tropical legumes with Rhizobium leads to increased productivity. If so, mechanisms of pre-inoculation need to be investigated.

Since that review was written, new technologies of trickle irrigation systems have come into more common use increasing the possibility of supplying small quantities of water when needed and within reach of plant roots with a minimum of waste,

While a great deal of work has been done to determine the effects on yield of irrigation at different times during crop growth, there is in many instances less detailed information on the effects of moisture stress on individual physiological processes.

Thus the effect of water supply on flower initiation, fruit set, fruit growth and composition have yet to be elucidated in many tropical species. While in the temperature climes, the major annual climatic changes involve fluctuation in temperature, in the tropics the major environmental change is in water supply and this supposedly has a major influence on flowering and fruiting patterns, particularly in perennial species.

Specifically then it is suggested that a collaborative programme be mounted on the effect of plant/water relations on physiological processes associated with yield and with particular attention being given to reproductive growth in tropical perennials. Thus methods and techniques that have been used in temperate species may be applied to less studied tropical species.

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II Animal Feeds

An important constraint to animal production in the tropics is the availability of feeds at reasonable cost. This is particularly important in respect of the supply of protein feed materials. The traditional sources of protein i.e. fish meal, soya meal and other oil seed meals are generally in short supply in the tropics and hence expensive.

A solution to the problem could possibly lie in the protein upgrading of other feeds e.g. carbohydrate materials, by the growth of microorganisms. The philosophy is not to produce SCP but to produce protein enriched materials in which only part of the substrate has been used by the microorganisms. Some work on this Village Level SCP Technology is already underway e.g. protein upgrading of cassava, coffee hulls etc but needs to be extended and rationalised.

Such studies could invlude:

- identification and studies of various microorganisms
- simple fermenter designs and fermentation techniques
- production of anti-nutritional factors and toxins
- solid state fermentation techniques.

These studies could be based on both carbohydrate breakdown systems e.g. starches and polymeric molecule degradation e.g. lignocellulosics.

III Genetic Engineering

This is taken to encompass propagation, somaclonal variation, *in vitro* selection and gene transfer by protoplast fusion and is not intended to be limited to genetic transformation by moving of specific genes, this latter being less appropriate for collaborative projects involving developed and developing Commonwealth countries.

Propagation *In vitro* propagation is now being used commercially in many noncultural species both for rapid multiplication and for obtaining disease-free material - particularly virus elimination. The techniques are relatively simple and the equipment needs of modest proportions. However the potential benefits are great.

Under this heading should be included germ plasm conservation - particularly of those species which do not produce true seed. It is assumed that this topic will be covered in another paper and so will not be discussed further here.

Evans and Sharp (in *Application of Plant Cell and Tissue Culture to Agriculture and Industry* - 1982) have suggested that large-scale propagation through somatic embryogenesis offers a potential avenue for exploiting hybrid vigour for species in which seed production not possible or is uneconomic.

Somaclonal Variations and *In vitro* Selections both aid the plant breeder in the quest for improved varieties, on the one hand by increasing variability and on the other by providing a new screening technique.

Gene Transfer by protoplast fusion introduces the possibility of combining traits from plant species which would not normally cross and so also gives the plant breeder greater variability. A major limitation to this technique, which involves the need for scientific work, is the fact that regeneration of plants from protoplasts of many economically important crop species has not yet been achieved.

While genetic transformation by moving of specific genes should not be entirely excluded from the CSC programme it is likely that the number of countries that can participate in collaborative projects in this field will be limited.

IV Postharvest Science and Technology of Perishable Commodities

INTRODUCTION

Comparison of current estimates of world post harvest food losses through quantitative and qualitative deterioration at 10-20% with estimates of world food shortage at 10% (approx.) has led to increasing awareness of the need for post harvest technology programmes to reduce food loss, as a necessary approach towards alleviating world food problems. However, this approach has led to emphasis on programmes in which measures calculated to effect immediate reduction of food loss are sought often without adequate understanding either of the food production/utilization system or indeed of the biological processes which lead to quantitative and qualitative food deterioration. As a result, the Kissinger policy initiative in the United Nations in 1975, leading to a resolution to reduce post harvest food losses in developing countries by 50% by 1985 does not now seem to be achievable. Moreover, whilst earlier estimates of post harvest losses in perishable commodities, i.e. roots and tubers, fruits and vegetables have now been substantiated, it now appears that losses in durable commodities, e.g. cereal and legume grains were over estimated in 1975. Therefore, proposals are here made for developing improved postharvest technologies for perishable tropical crop commodities, based on better understanding of both the pre and post harvest biology of these commodities, under the following headings:-

A. Overview of Perishable Foodsupply, Biological Constraints and Postharvest Technology

B. Preharvest Problems

C. Postharvest Problems

D. Priorities and Institutional Approaches to Research and Development.

A. OVERVIEW OF PERISHABLE FOOD SUPPLY BIOLOGICAL CONSTRAINTS AND POST HARVEST TECHNOLOGY.

Research on tropical roots and tubers, fruits and vegetables has received much less attention than that on tropical cereals and as a result production of the former commodities increased by only 1% compared with 2.5% for cereals over the last 10 years. World production levels are at 182,000, 130,000 and 113,000 tons (approx.) for roots and tubers, fruits and vegetables, respectively and important commercial species include the cassava, sweet potato and yams among roots and tubers; tomatoes, melons, onion, cabbage, pumpkins, peppers and eggplant among the vegetables and oranges, mango, pineapples, bananas, plantains, avocado and papaya among tropical fruit. However, although these commodities contribute considerably to the nutrition of peoples in developing countries, their mean per capita consumption is still low. Thus, per capita consumption of vegetables in developing countries is estimated at 100 gm compared with 220 gm. in developed countries and consumption of tropical roots and tubers and fruits is also low compared with, say in Europe.

As research and development programmes in perishable crop production lead to agricultural growth in developing countries, an increasing percentage of the production is being marketed at locations far removed from production centres. Moreover, reduction in food importation to conserve foreign exchange has put increasing demands on the local food production system. However, the resulting increased commercialization of post harvest activities has not been paralled by investigations on pre and post harvest processes directly affecting the development of appropriate commercial postharvest technology operations. It is proposed that these investigations might include:

Preharvest studies on

- Off season production to alleviate seasonal food availability.
- Selection of cultivars with improved harvesting, handling, storage and processing characteristics.
- Cultivation practices which increase shelf life and

storage life of perishable commodities, leading to:-

Postharvest studies on

- control of ripening in tropical fruit
- control of dormancy in tropical tubers
- control of senescence in tropical vegetables.

Such investigations are more critical for improvement of the utilization of perishable commodities than with durables, since increased production will lead to increased post harvest losses in the absence of a well defined strategy to prevent them, because of the high susceptibility of the former species to post harvest deterioration. Such losses will negate the efforts, particularly of well planned production programmes.

B. PREHARVEST PROBLEMS

The preharvest problems of off-season production, selection of cultivar with improved harvesting and post harvest potential and adoption of cultural practices to increase ease of harvesting, storage and commodity quality, critical though they are, are considered more appropriate to production programmes. They include:-

- Development of off-season flower induction and fruit development and crop cultivation strategies.
- Selection for dwarfness, organ conformation and display, quality and storage characteristics.
- development of cultural practices of spacing (including high density planting) fertilization and preharvest pest and disease control in commercial organs.

However, in many cases production researchers need to be sensitized to the overwhelming importance of criteria which determine the amount of the commodity that is actually used by the consumer rather than the magnitude of on farm yield. It is proposed that support should be given to a review of the need for such sensitization to postharvest problems in major existing preharvest production programmes, e.g. in International, Regional and Nation

Centres of Research.

C. POSTHARVEST PROBLEMS

i) *Control of ripening in tropical fruit.*

In order to reduce losses and increase utilization of tropical fruit, understanding of the process of ripening in these commodities is critical. Information on ripening processes already obtained with some species, e.g. banana, avocado, mango, melon, needs to be investigated in other species to develop a more comprehensive understanding of the process. These studies should use germplasm with wide variation in rate of ripening and should seek to refine both methods of selecting cultivars for good ripening characteristics as well as to develop practical measures for controlling ripening. Comparative physiological and biochemical studies on respiration, ethylene biosynthesis, cell wall metabolism and hormonal control of ripening are proposed using cultivars with defined ripening characteristics. Experimental trials with low temperature, hypobaric, controlled atmosphere and hormone-induced storage should be conducted simultaneously with more basic studies.

ii) *Control of Dormancy in tropical roots and tubers*

Post harvest deterioration in tropical roots and tubers leads to perhaps the highest losses of calorie foods in the tropical developing countries. The critical processes involved are post harvest physiological and pathological disorders in cassava roots and termination of dormancy through sprouting in yams and sweet potato tubers. It seems significant here that where there is no mechanism for generation of new plants in the cassava root, that the storage life of the roots is very short, compared with tubers in other tropical root crop species. Comparative biochemical and physiological studies on dormant and

sprouting roots and tubers from cultivars with known storage potential, including investigations on hormonal control of dormancy and tuber tissue deterioration are proposed. Investigation on effects of physical damage on storage capacity are also of great importance. Again the objectives suggested are both to develop refined selection tools for improved storage characteristics as well as to formulate practical low cost measures for tuber storage.

iii) *Control of senescence in vegetables*

Leafy vegetables e.g. *Amaranthus* and Aroid leaves and immature fruit vegetables, e.g. cucumber, papaya banana are important local sources of protein, calories and vitamin supply in the tropical countries. Yet little attention has been given to extension of the storage and shelf life of these commodities by prevention of post harvest senescence and deterioration. Thus, although low temperature storage has been used, high energy costs warrant investigations on physiological and biochemical control of senescence, including use of hormones, modified atmospheres and hypobaric conditions towards controlling water loss, commodity quality and tissue integrity of commodities whilst reducing or eliminating the necessity for low temperatures. Again, comparative studies with a wide range of cultivars are recommended, and distinction should be made here between short term and long term storage investigations.

D. PRIORITIES AND INSTITUTIONAL APPROACHES TO RESEARCH AND DEVELOPMENT

It is suggested that post harvest studies should be encouraged in Universities and National Institutes because the problems involved are often location-specific. However, International Centres could play an

important role in postharvest technology studies for root crops by defining storage characteristics of promising cultivars generated in breeding programmes for cassava (CIAT) and yams and sweet potato (IITA). Such definition is the starting point for further post harvest study. Alternatively, post harvest studies on tropical fruit and vegetables must be confined to trppically located regional/national institutes in the absence of an International Centre for post harvest studies located in the tropics. However, TPI (London) might contribute to these investigations by deploying researchers to national institutes on specific projects.

Priority attention should be assigned to the root and tuber, fruit and vegetable commodities of greatest national or regional economic importance by individual Universities and National Institutes in developing countries. However, three collaborative networks for post harvest studies on roots and tubers, fruit and vegetables, respectively, should be established and a single institution in a tropical developing country given support towards establishment and service of the network for each commodity group.

Tropical Forest Ecology

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Justification

Tropical forest covers an area of just under 20 million sq. km. in all three continents. The largest proportion, 46%, lies in South and Central America, 36% in Africa and 18% in Asia.

Not only do the tropical rain forests, at the wetter end of the spectrum, represent the richest and most complex ecosystems on earth; but the range of tropical forests contain very large numbers of different communities distinguished by history, climate, altitude, topography and soil. Tropical forests are therefore a treasure house for the study of ecology and evolution.

These forests and the lands that they cover are being changed very rapidly. Although the rate varies from country to country, and some areas may remain relatively undisturbed for some time, many types have already been totally destroyed and others are changing so swiftly that there is little time left if they are to be adequately studied. There is therefore great need, and urgency, to study the rain forest in its natural state to understand the evolutionary mechanisms that have been proceeding there for millenia; and to be sufficiently familiar with the nature of the changes that are taking place to guide development into paths that damage the environment as little as possible.

It has been estimated by a Food and Agricultural Organisation/United Nations Environment Programme (FAO/UNEP) study that tropical forest is being converted to other uses at a rate of 11.3 m ha a year. Most of this is for agriculture of which only a small proportion is planned, the remaining conversion being due to disrupted systems of shifting cultivation or to uncontrolled colonisation by the landless poor. In addition 4.4 m ha is logged each year. Logging need not, by itself lead to land degradation if it is well-conducted and followed immediately by proper management for sustained timber production: but this only occurs so far on a small proportion (estimated at 4.4%) and, without it, the land may very rapidly become degraded. For example, over 3 million hectares of logged-over forest was burnt last year in Kalimantan killing all trees, due to the the unfortunate combination of logging and unprecedented drought; this, in a forest that never burns naturally.

In addition, therefore, to the merits, in terms of pure science, of studying the ecology of the tropical forest, there are very strong practical reasons for doing so, related both to its development and its conservation.

There is thus a compelling general case for the development of a scientific programme in tropical forest ecology. There are, of course, already a number of initiatives in this field (for example, Man and the Biosphere (MAB) project 1 and the International Union of Biological Sciences (IUBS) proposal for a decade of the tropics), but there is much to be said for a Commonwealth programme to complement and strengthen these.

In the field of pure science, a Commonwealth programme could build on the proposed Royal Society programme in South East Asia. The first part of this is taking the form of collaborative work with Malaysian scientists based principally on the Danum valley in Sabah. It has as its main objective the investigation of the dynamic ecological processes and evolutionary mechanisms operating within tropical rain forests by studying them under undisturbed conditions and under various types and degrees of disturbance. It is intended at the same time to strengthen scientific links between the UK and Malaysia and to provide the opportunity for training and institution building.

Considering the importance and urgency of the problem, it seems incredible and highly culpable that there is not a much greater scientific effort being put into: describing and understanding tropical forests and their organisms while they still remain to be described, and: accumulating the knowledge and understanding to decide (a) what should be preserved and how; and (b) how forest lands can be changed and developed in ways that are ecologically sustainable and socially acceptable.

The Commonwealth could act as a new focus for a coordinated effort. Apart from the usual advantages attending Commonwealth programmes compared with fully international ones, there is the important consideration that most of the Commonwealth countries lie at least partly within the tropics. Some, notably Malaysia, Papua New Guinea, Nigeria, Bangladesh, Ghana and Uganda have important remaining areas of tropical rain forest; others, Kenya, Tanzania, and India, severe problems in the sustainable development of their drier forest lands; and the temperate countries of the Commonwealth have both an interest and a competence in tropical forest ecology.

Contrary to the present trend in much of contemporary science, there is a pressing need in the developing countries of the Commonwealth for field studies with the central practical objectives of designing ecologically sustainable systems of land use closely fitted to the needs of their peoples and of preserving selected important elements of their natural ecosystems in the most cost effective manner. There is an equally pressing need for people who have skills in these aspects of applied ecology and who can effectively bridge the gulfs between the biological and the human sciences. Skills in taxonomy have been allowed to decline to a dangerously low level.

The General Nature of a Programme

The future of tropical forest lands lies in three directions, if it is not to become degraded:

(a) It may be transformed to productive agricultural or forestry systems: food or cash crops; plantation forestry; or agro-forestry. All of these, if sites are well chosen, conversion well planned and the resulting crop is well managed, will retain the fertility of the soil and the physical characteristics of the forest in relation to climate and hydrology.

(b) It may be managed for the sustained yield of timber and other forest products.

(c) It may be retained almost intact as forest for the protection of catchments or as nature reserves.

All of these require ecological research (including research into the local people inhabiting the forest and those who will be affected by the development of these forest lands).

These studies would broadly fall into the following categories:

(a) study of the distribution and range of variation of eco-systems;

(b) study of the identity and taxonomy of organisms;

(c) monitoring of change in nature, extent and distribution of ecosystems;

(d) study of the internal dynamics of a range of tropical forest ecosystems in order to determine their functioning without human intervention and their changes in response to fluctuations and trends in change of climate;

(e) the relation between present forest characteristics (composition, structure, soil etc.) and the suitability of these lands to be used for other purposes;

(f) knowledge of the potential of tropical forest species for economic use and detailed knowedge, in the case of key species, of their autecology to enable sustainable management systems to be devised (eg for the production of timber, rattan etc.);

(g) knowledge of the range of variation, centres of biological diversity, endemism etc., which would enable the best choice to be made of areas for conservation;

(h) the best distribution of nature reserves and corridors between them to enable the diversity of species and geno-types to be most economically preserved;

(i) anthropological knowledge of those dwelling in and near the forest designed to bring about smooth and acceptable change where change is necessary.

It is notable that many of these are included within two of the three major needs for future research identified by the 17th International Union of Forestry Research Organizations (IUFRO) Congress in 1981, based on an assessment carried out for IUFRO by the World Bank and FAO:

- research related to the contribution of forestry to rural development including productive and protective functions of trees and forest, eg greater emphasis on research into framing systems incorporating trees and on watershed protection;

- research related to more effective conservation and management of tropical forest ecosystems with special reference to protection of the environment.

Certain aspects of any programme based on a selection of items (a) to (i) above would link closely with a number of the other subjects proposed for the Expanded Programme of Commonwealth Scientific Cooperation: (1) Remote Sensing; (2) Genetic Resources (particularly of timber trees and unexploited plants of the forest); (3) Integrated resource management; (9) Energy (particularly fuelwood and catchment hydrology); and (12) Epidemiology.

The Future

To undertake a sustained and comprehensive programme in all of these subjects would require a carefully planned and strongly financed collaborative programme. Efforts so far have been 'fiddling while Rome burnt'. The scale, significance and irreversibility of the changes now occuring do, however, in my view, require a radical change of heart and a very strong injection of finance comparable to that regularly invested in aspects of the physical sciences and in space research.

In the absence of a powerful, comprehensive programme of this kind (which would need its own planning mechanism) all the items listed above could be developed in a more humble way; they could be planned for the range of postulated time-scales; and there are institutions in all the larger Commonwealth countries which could collaborate.

Information

In the field of information, it would seem highly desirable to build on the very effective services already available with the Commonwealth Agricultural Bureaux. This service is deficient, however, in the field of wildlife and conservation. A proposal, still looking for funds, which is designed to fill this gap, is given below:

An International Wildlife and Conservation Information Service (WICS)

Discussions have been going on for some years about the possibility of creating an international bibliographic abstracts data-base, that would serve everyone with a serious interest in plant and animal wildlife, in the context of nature conservation. The idea originated partily in Oxford, England, and partly in Fort Collins, Colorado, but has been very widely supported, and now has the backing of International Union for the Conservation of Nature and Natural Resources (IUCN) and World Wildlife Fund (WWF). The latest step towards its realisation is the news that the UK Nature Conservancy Council (NCC) is prepared to consider material assistance in funding the service, helping it to find a home, and allowing it to use the existing NCC data-base and computer system. The NCC would also be prepared to play a part in the of management, including the provision of facilities for it to function effectively.

The heart of the 'WCIS' would be a small coordinating editorial office in proximity to the NCC central library, at present located in Banbury, England. Its functions would include preparing abstracts in-house, collating abstracts from other cooperating centres, keeping track of the literature as a whole, and developing ancillary activities, such as specialised bibliographies, 'selective dissemination of information', literature reviews, computerised library catalogues, 'document delivery' (photocopies), etc. The 'carrier language' would be English, but corresponding databases in other languages should be developed at centres in appropriate countries as soon as possible.

One approach would be to operate and market an online retrieval service much as the NCC handles its smaller database now, through a commercial agency or agencies, and at the same time to make it available for the production of 'hard copy' in the form of an abstracts journal, through a commercial publisher. The journal could also carry features such as news, review articles, thesis summaries, etc. A preliminary study suggests that the central office could be set up and operated for about a quarter of a million dollars, spread over

three to four years. After that the service could be made to generate its own finances, possibly with an interim period of reduced subsidisation. Absolutely firm estimates of income are not possible, but on the analogy of similar services in other fields eventual self-support is a realistic prospect.

The service might be under the aegis of UNEP, with additional support from IUCN and WWF. The immediate need is to find sponsors in other countries to match NCC's offer, both in contributions to the project funds and in continuing commitments to provide bibliographic input.

Integrated Resource Management

Malcolm Hadley
U N E S C O

1. Introduction

Vast sums of money are spent each year on projects of development and management of renewable natural resources. In many developing countries, in particular, the development of national resources is seen as a key to the overall national development strategy. But often the results of these projects are not commensurate with inputs, and the expectations and aspirations of both governments and local populations are left unrealized.

One observer (1) has commented, for example, that «in the last 15 years the equivalent of 600 million US dollars in international development funds has been invested in the rangelands of Africa in an attempt to develop a strategy of resource exploitation that would be as efficient as traditional pastoralism but that would have a chance of coping adequately with the greatly changed conditions of late twentieth century African life (which traditional pastoralism, for better or worse, cannot). There is very little to show for that investment.»

Reasons for such shortfalls between promise and reality are multiple and complex, as are the symptoms and consequences of insensitive resource development and management (2). Thus, much economic development, particularly that having a primary focus on massive capital and technological inputs, leads to uniformity. So-called 'western models' of development are often imported without due regard to the diversity of local situations and cultures. Sometimes development programmes may be unduly shaped by donor rather than recipient countries, by central institutions rather than local populations. Imported technologies may be inappropriate, and outrun the local capacities to absorb them. Socio-cultural systems are disrupted. The traditional and varied adjustment mechanisms that different societies have developed for coping with change break down.

A second major critique is that sectoral interests and short-term perspectives dominate much resource development planning. There is fragmentation of research, administration and decision-making. Priority may be given to costly projects having high prestige and immediate visibility, rather than those which could bring gradual change and long-term

benefit. Development strategies based on foreign assistance are particularly prone to collapse after the termination of a particular scheme. Local capabilities for ensuring a sustained follow-up are often lacking. Procedures for evaluation are inadequate.

A third characteristic of many resource development schemes is that local populations and other interested parties are not fully involved in the processes of planning, decision-making and implementation. The result is often an alienation of local populations, and heightening of the disparities and gaps between different groups and levels within the national society.

A fourth tendency of many programmes and strategies of resource development and management is that they do not seek to encompass projects which are complementary in scope and in purpose. Opportunities are lost for linking projects, in time and in space, in ways that are mutually supporting and beneficial. The possibilities and advantages of concerted multi-national action are also ignored or underestimated.

In what follows, insights are given on some issues and concepts in integrated resource management. Certain available approaches and techniques are described, drawing on examples of research and training activities from Unesco's Man and Biosphere (MAB) Programme, and some suggestions provided on possible areas of activity within a Commonwealth context.

2. Some issues and concepts

2.1 Policy and planning as the entry point

Much scientific research has no impact on resource management. In some (if not most) cases, this is because no such effect was intended; much ecological research (which is of a generic nature) comes under this category. But even with much practically-oriented site-specific research, the results are not used - in part because insufficient attention is given to the needs, constraints and time scales of the decision-making process. Certainly, the rationale that a research project is interdisciplinary and deals with an environmental problem is no longer sufficient. Political decision-makers, policy advisers, agencies granting funds for research, and to some degree the general public, are placing increased emphasis on funding research that is focused on problems relevant to the society. This trend

poses challenges to researchers to provide information that responds both to the short- and medium-term needs of the decision-makers, and to undertake research that is rigorous, challenging and enriches the theory and knowledge of science (3).

2.2 Information needs for decision-making

The needs of the decision-makers for information should be recognized as different from those of science. In science, precision and the highest possible quality of data at the end of the project may be the prime goal; for policy-makers, timely, less precise results are likely to be more valuable. Scientific output, however accurate, cannot contribute to policy after the decisions have been taken. A research project oriented to the needs of resource management and planning should therefore be prepared to provide results in successive approximations throughout the life of the project. Policy-advisers and decision-makers, on the other hand, should recognize the uncertainty and imprecision of the scientific information and formulate policies that are flexible and adaptive.

In shaping the input of science to environmental planning, it is essential to recognize that decisions about management of the environment are made at many levels in the social hierarchy (4). There are the people such as farmers, fishermen, foresters, urban developers, who actually manage the environment directly. Then there are the advisers who guide the resource manager (eg agricultural extension workers) and the regulators in control agencies who provide instructions on standards to be met or actions to be avoided. Behind these groups are national or regional policy-makers in government, or senior managers in regulatory agencies, who determine what the standards imposed by regulators should be or what production goals the advisers should work towards. The people who make up this direct interactive system of decision-making have very different needs for information and often work at different time scales. These differences need to be clearly appreciated by the wider community (including the scientific community) whose interests, perceptions, demands and skills help to shape and influence environmental policy and resource management.

Other considerations need to be taken into account in the process of designing a research programme geared to the needs of integrated resource

management. These include (3):

- Ensure early involvement in the issue at hand of 'stake holders' (i.e. decision-makers, policy advisers, other principal clients and constituencies), to identify issues more precisely and to formulate questions for research;

- Understand the time constraints of the decision-makers and the policy-advisers, both from the point of view of urgency of decisions to address the issue (i.e. priority) and political considerations and timing;

- Provide policy advice, based on the available information, within the time constraints faced by the decision-makers and policy-advisers;

- Provide feedback to various 'stake holders' in language and terms understandable by the target audience (i.e. for decision-makers, policy advisers, scientific community and the general public, provide executive summary, policy analysis paper, scientific paper and non-technical information, respectively);

- For complex problems involving many government agencies, «disaggregate» scientific findings targeted specially at the area of responsibility of individual agencies;

- Ensure continued interaction with and involvement of various 'stake holders' during various phases of the research programme, in order to maintain their interest and to obtain their feedback for any mid-course adjustments in the research programme;

- Instead of presenting a single solution, provide a number of policy options and describe their possible implications to the decision-makers and policy-advisers, so that they can exercise a choice of actions.

2.3 The multi-dimensions of resource management problems

The search for integrated approaches to resource management is conditioned by at least three characteristics of these problems: their variability and heterogeneity, their complexity and their relatively low degree of predictability (5).

First, problems and priorities differ from one country to another, from one region to another. There is wide variation in ecological and socio-economic situations, even within a particular country. Any programme concerned with problems of people's use of resource and focussed on their needs must reflect the extreme diversity of the conditions under which they live.

Second, problems of resource management are more complex than they were even a few years ago. A growing population is exerting increased pressure on the land and its resources. In many countries, some resources, once readily available, are becoming scarce. The rate of change is accelerating, and what were until recently mostly local concerns can affect or be affected by events far away.

Third, problems of land use and resource management are changing all the time. The rate and scale of this change 'is perceived by many to be transcending the adaptive capacity of individuals, governments, industry and nature'(6). Many management policies that have succeeded in the short term have failed over the longer term, because of their success in reducing variability, because they failed to keep track of the 'moving targets' of rapidly evolving land use problems, because they were not able to predict what variables would trigger surprise and change, or because they were not able to adjust to change.

A major problem for the decision-maker - and for the scientist who seeks to inform and advise the decision-maker - is how to live and deal with this heterogeneity, complexity and uncertainty of present-day situations and problems. A consequence of the heterogeneity of situations and problems is the need to accept a range of responses and approaches to problem-solving; no single approach is likely to be applicable or successful on a worldwide basis. A consequence of the complexity of problems is the need to seek the participation of three main actors on the stage where those problems need to be solved: scientists from a range of disciplines, decision-makers and local populations. A consequence of accepting that a certain proportion of events cannot be predicted is the need to build-in the possibility of flexible response within the decision-making and research system - so that even the unpredictable is planned for.

2.4 Integration among scientific disciplines

The search for sustainable use of renewable natural resources and improvement of environmental quality impinges on a whole series of social, cultural, economic, biological and physical considerations. Recognition of these multiple facets has led to a number of attempts to bring together scientists from a range of disciplines to address specific environmental problems. Different approaches have been tried out as a focus for integration. Within the MAB Programme of Unesco, for example, these approaches have included human ecology, human use systems, perception studies and integrated models (7). Many difficulties have, however, been encountered in bringing together scientists from different disciplines and backgrounds. Barriers to integration include historical, institutional and perceptual constraints, as well as problems at the conceptual level. A number of ingredients for fruitful cooperation have emerged, including the orientation of projects towards management decisions or policy alternatives, the involvement of local people, the adoption of a strong modelling focus, the key role of internal communication and the project leader in the integration process, the importance of small scale in project design. A major need is for working models that can integrate natural and social science contributions in a form that can be incorporated into management decisions.

Other scholars have argued that the goal of integration still seems beyond reach. Even in well intentioned and well designed efforts to incorporate different disciplines as equal partners from the outset of the research or planning process, often a particular approach tends to predominate Rather than continue to expect a great effect in seeking integration, an alternative approach might be to encourage a variety of approaches which could lead to different but complementary results (8). This would give recognition to the truism that there is no single approach capable of giving full weight to each of the major relevant variables in the analysis of relationships between everyday life and natural processes. Any approach is by definition selective. No approach can encompass everything. Any approach is likely to have something to learn from others. And therefore what is required is an exchange between people with different approaches to a central environmental problem. By viewing different approaches as complementary and not competing, the groundwork has been prepared for effective collaboration among people with different skills, as well as promoting improved communication and understanding among the different actors involved in land use planning and resource management.

2.5 Differing and changing perceptions

Understanding of the environment is embedded and therefore conditioned by social and cultural context. The environment is not the same objective reality for all, but varies from one observer to another and from one socio-economic or cultural group to another. A farmer, a pastoralist and a forester will each have different ideas about the best way of using a given piece of land. Industry may think very differently about the way to manage a forest than a national forestry administration. Tourists and local populations will often have different perceptions about the desirable features of a given coastal environment. Perceptions will vary from one geographic region or from historical period to another. Sewage, for example, has long been thought of as a resource in many Asian societies, but only recently has it been thought of in these terms in western industrialized countries, and even then only by a relatively small segment of the population.

Two relatively recent changes relating to environmental perception and its investigation have important implications within the context of resource management. A first change is that studies on perception have facilitated the involvement of local populations in discussions and decisions relating to the environment. A second change is in people's attitudes to environmental issues. Understanding of the need for careful husbandry of physical and living resources has spread remarkably, and there has been a change in many countries in the usage and meaning of terms such as development and conservation. But at the same time, much remains to be done to promote ideas such as sustainability within the economic planning of government (9).

3. Techniques and approaches

3.1 Economic analysis

In times when space and nature were not regarded as a scarce commodity, economics did not show much interest in environmental problems (10). But the last twenty years or so have seen a shift in emphasis. Since the 1960s, there has been an avalanche of economic literature dealing with environmental issues. A wide variety of economic approaches to environmental issues have been developed, dealing with analysis of the environmental repercussions of economic activities as well as of the economic effects of environmental change.

Recent developments have expanded the techniques and approaches which economic planners can bring to bear in environmental planning (11). A number of classes of environmental-economic models have become available, including material balance models, input-output models, integrated environmental models, dynamic stock-flow models, spatially-oriented economic-environmental models, and environmental evaluation models (10).

In spite of progress achieved, many methodological shortcomings and limitations hamper actions at the economic-environment interface. A basic (some would say intractable) problem is that of being able to put a price tag on environmental commodities, many of which are intangible. The appraisal of the benefits and costs of individual development projects generally suffers from very narrowly defined boundaries for economic analyses. External offsite and non-market impacts need to be included if balanced assessments are to be carried out, but these are often missing ingredients in the development planning process in many countries. Sometimes, there is lack of political will to carry out balanced assessments. Other times, the missing ingredients are lack of know-how and trained personnel (see Section 4.2).

3.2 Integrated cartography

Governments have tended to entrust land use planning and resource management to single purpose agencies in particular economic sectors. Not surprisingly, there exist a variety of methods for assessing resources which are specifically oriented to the interests of the individual sectoral agencies (e.g. forestry, agriculture, water). Relative little attention has been given to assessing the opportunities for integrated development of various sectoral activities (e.g. in coastal areas, forestry and fisheries associated with mangrove) and to the impact of one form of development to another.

Increasingly, however, tools are becoming available for helping in the planning of multi-use activities, and in the definition of the development potential or constraints of different land areas. Integrated cartography of the environment is one such approach being developed and tested by groups in several countries, such as an interdisciplinary team at the University of Caen, France, working within the framework of the International Geographical Union (12). The technique shows promise as a tool for land use

planning. It combines the contributions of remote sensing and more traditional approaches and enables account to be taken of the phenomena of correlation and potentiality as well as dynamic changes in components of the environment such as soil, air and water. Mapping is carried out at a scale of 1:50 000, and maps have now been produced for a variety of situations, including Lower Normandy in France and the Save region of Benin. The approach can readily be adapted to different settings; for example, special attention is given in the humid tropics to soil and hydrological factors, in arid zones to soil structural processes and in temperate zones to issues relating to leisure, industrialization and urbanization.

3.3 : Systems analysis and modelling approaches

During the last ten years or so, systems analysis has become increasingly recognized and adopted as a framework and strategy for tackling resource management problems. It is not merely a technique, or a group of techniques, such as probability theory or mathematical programming, but should be thought of as a broad research strategy - a strategy that involves the use of techniques, concepts, and scientific, systematic approaches to the solution of complex problems (13). It is a framework of thought designed to help decision-makers choose a desirable (or in some cases a «best») course of action. The approach may entail such steps as: recognizing the existence of a problem; defining and bounding the extent of a problem area; identifying a hierarchy of goals and objectives and examining the value of trade-offs; creating a range of alternative and appropriate solutions for careful examination; and implementing the results of the analysis.

Applied systems analysis is designed to promote good decision-making. As a process, it is intended to focus and to force hard thinking about large and usually complex problems. Within the framework of the strategy of systems analysis is included a wide range of possible techniques, including operational research and management science, cost effectiveness and cost benefit analysis, planning, programming and budgeting, decision analysis and cybernetics, information theory and the management of information, control systems, computer science, dynamic modelling and statistical analysis.

Systems analysis is not, of course, a panacea, and it is prudent to recall some warnings about its present shortcomings (13). Thus, there have been communication difficulties in some successful research projects which have

used systems and modelli ıg approaches as a basis for the investigations. There is concern that many scientists wishing to use systems analysis and modelling have become reductionist. In some cases, individual scientists, assigned their part of an overall resource management project, have become enthrilled with the science of the problem. Many model builders are more interested in the construction than the utilization of models, and in consequence many available models address problems that model builders perceive rather than problems that actually require solution. There are also outstanding problems in the basic theory of systems analysis and modelling. Some of these problems are concerned with the verification and validation of theoretical models by direct experimentation, and by sampling from real-life systems. Others are linked to the relative merits of «top down» and «bottom up» approaches of the definition and modelling of subsystems. Finally, and most importantly, many countries lack personnel trained in the methods and techniques of systems analysis. Even though the approach does not necessarily involve the use of advanced analytical techniques, it represents a level of scientific training that still has to be achieved in many countries.

While present difficulties and constraints should not be discounted, it is worthwhile underlining the very real progress that has been made in applying systems approaches to resource management problems. Among the topics where systems analysis has been shown to be particularly suitable are forest succession, dynamics of human settlements, and regional planning and land use management in marginal areas (13). Recent advances in the development of computer and programming languages have meant increased power at a reduced cost, so that relatively cheap microprocessors can now handle calculations and information processing which a decade ago could only be tackled by the use of large and expensive mainframe computers. Furthermore, groups in a number of countries and institutions have been testing diverse approaches and procedures for linking systems analysis with the needs of environmental planning and resource management. One such approach is described in the following section.

3.4 Adaptive Environmental Assessment and Management

The approach of «Adaptive Environmental Assessment and Management» has been developed mainly by C.S. Holling and colleagues working in the Institute of Resource and Ecology at the University of British Columbia and

more recently at the International Institute of Applied Systems Analysis. The approach is a carefully designed and scheduled series of alterning workshops and research periods. It brings together scientists, managers, policy-makers and members of public interest groups in interdisciplinary workshops at an early stage of the planning processes. Participation of these various groups facilitates a balanced consideration of relevant issues and identification of possible conflicts early in the process, thus increasing opportunities for their resolution before major decisions are taken. Computer simulation modelling and other techniques of systems analysis are used to limit the scope of the environmental assessment to key factors affecting decisions. These techniques help identify important gaps in information that need to be filled before an important decision can be taken. A characteristic of the interactive simulation process is the production of various scenarios on the likely consequences of alternative actions.

The approach has been useful in addressing environmental problems in a variety of settings and regions. Among the types of problems addressed have been: how to reconcile winter and summer tourism with traditional agriculture and forestry land uses in an Alpine valley community in Austria; assessment of cottage development along lakeshores in Ontario, Canada, including improvement of available methods for evaluating the impact of lakeshore developments on wildlife, fish and water quality; development of an integrated, management-oriented simulation model of a river basin in Thailand, taking into account the biological, physical and socio-economic aspects of the system.

Training programmes to increase local expertise in using the approach and its techniques, have been carried out in a number of countries. Given that the initial thrust for adaptive environmental assessment and management has come from Canadian scientists, possibilities for expanding such training might usefully be explored within a Commonwealth context. One example might be the application of the approach to environmental planning and integrated resource management in small island situations in the Caribbean or Pacific regions.

3.5 Environmental impact assessment

Environmental impact assessment is an approach to evaluation that has been developed since the 1960s as an outgrowth of technical feasibility

studies and cost benefit analysis. It has evolved as a comprehensive approach to evaluation in which environmental as well as economic and technical considerations are given proper weight in the decision-making process (15). The use of the approach has widened with practice, and now often encompasses a number of basic questions relating to a given development. Is the development required? What are the relevant alternatives which could provide the same benefits and how do respective environmental impact assessments compare? What is the appropriate level of public safety in relation to hazardous technologies? What degree of environmental protection should be guaranteed for areas of significant ecological and landscape value?

Environmental impact assessment has become institutionalized in a number of countries (e.g. USA, Canada). Though there is a large degree of similarity in philosophy, there are differences in the application of the process from one country to another, and many criticisms have been expressed of environmental impact assessment as it has been put into practice: for example, that it is often out-of-phase and marginal to the economic and political decision-making process, that it is a sop to environmental and community groups. On the other hand, environmental impact assessment has spawned a range of techniques, methods, and approaches of interest within the broader processes of environmental planning and integrated resource management.

Within the Commonwealth context, considerable expertise on environmental impact assessment is available, in countries such as Canada (16). Training programmes include courses organized by the Environmental Impact Assessment and Planning Unit at the University of Aberdeen, most recently a one-week seminar held at the University of Hong Kong in January 1984. Many manuals have been produced giving advice as to how impact assessments can be undertaken. Most have been produced in the United States, and have tended to deal with the impacts of different types of civil engineering projects, as well as other developments such as waste-water treatment plants, naval developments, nuclear power stations, coal-fired power stations, airport developments, etc. (17). Though some broadly based handbooks and manuals are available (18), most guidelines have been developed on the basis of experience in industrialized countries, in the temperate zone. Methodological handbooks tailored to the special needs, interests and present capacities of developing countries are generally lacking.

3.6 National conservation strategies

As part of the implementation of the World Conservation Strategy (19), IUCN has promoted the need for and assisted in the development of national conservation strategies. The stated aim of a national conservation strategy is to enable a country to better determine how to achieve sustainable development through improved resource management (20). On the basis of review, analysis and assignment of priorities, a national conservation strategy is intended to define the best possible allocation of human and financial resources to achieve the goals of conservation for development. The purpose is not simply to prepare a strategy as such, but also to set in train and encourage an appropriate understanding and knowledge within a country of the interdependence between conservation and development and to ensure the ability and commitment to implement the strategy. As of December 1983, national conservation strategies had been or were being prepared in 35 countries, including a number of Commonwealth countries such as Australia, Belize, Fiji, Malaysia, New Zealand, Nigeria, St Kitts and Nevis, Sri Lanka, Uganda, United Kingdom, Zambia, Zimbabwe (20).

4. Examples of concrete actions

4.1 Pilot projects

In recognition of the variability and complexity of resource management issues in different parts of the world (Section 2.3), one approach to harnessing the contribution of science to resource management is through the setting up of pilot research projects in particular geographic areas, chosen as far as possible to encompass problems and situations of regional as well as local interests. Within the MAB Programme, pilot projects have been set up by national participating institutes in a variety of ecological and geographical situations, and focussed on a range of resource management issues considered of priority in the countries concerned. Within the Commonwealth group of countries, for example, these projects have included work on:

- population-environment-development interactions in the eastern islands of Fiji (21);
- management of limited resources in a group of densely-populated small island countries at different stages of development in the eastern Caribbean (22);
- social and environmental effects of clear felling of tropical forests in the Gogol river valley in Papua New Guinea (23);

- past and present interactions between pastoral man and grassland environments in the Waitaki River Basin in New Zealand, as a basis for a sustainable future in a regionally planned context (24).

- biological basis for improving soil fertility and forage production in Guinean savanna in Nigeria, with particular reference to fire effects and tree-herb interactions (25).

Each pilot project has its own goals and flavour, content and activities, autonomy and organization, strengths and weaknesses. But an idea of the sorts of approaches followed in these and other pilot projects within MAB can be provided by a description of one relatively advanced pilot project, that on rehabilitating degraded arid lands in northern Kenya.

The Integrated Project in Arid Lands (IPAL) is a pilot project of applied research, training and demonstration, focussed on a 22.500 km^2 area in the Marsabit district of northern Kenya (26). Launched in 1976, the project has evolved from a first phase (1976-79) of basic resource surveys and investigations of plant and animal ecology to a second phase (1980-1983) of redefined research (broadened to include such activities as human ecology) and the drawing up of resource management guidelines. The research phase of the project ended in late 1983, and has given rise to an integrated resource management plan for the Rendille region and the proposed creation of a permanent Kenyan Arid Lands Research Station in Marsabit.

It is still too early to establish a balance sheet on the pilot project in northern Kenya, but a certain approach to integrated resource management has been tried out and shown to hold promise. Several ingredients have contributed to the success of the IPAL operation.

A first ingredient has been the clarification of the underlying reasons for resource degradation in the study area - an understanding which has in part resulted from the in-depth investigations on the complex interrelationships between population increase, socio-economic change, partial sedentarization, overgrazing, availability of permanent water points, desertification and drought.

Second, the project has been firmly based on a overall working hypothesis, which can be summarized as follows: that, through research and training, improved land use systems can be devised to reverse the trend of land degradation and to sustain land production for the needs of a growing (and partially sedentarized) pastoral population of northern Kenya.

Third, the project has as its major objective the drawing up of resource management guidelines directed towards achieving a sustained balance between pastoral production and consumption, while taking into account the requirements of the growing and increasingly settled population; the project had a mandate to elaborate practical modifications and alternatives to the traditional livestock-based economy which would permit the rehabilitation of already degraded lands.

Fourth, the preparation of concrete recommendations and management plans for integrated development called for in-depth studies on a large spectrum of topics. These ranged from the climate, soils and vegetation of the area to the chemical analysis of plant species in the diet of the different types of livestock, to studies on the perception by the pastoralists of the changes taking place in their lives and on their aspirations for the future. Consequently, the work required the collaboration of a number of disciplines including plant and animal ecology, veterinary sciences, physical and human geography, range science, social anthropology, agricultural economics, hydrology and climatology.

A fifth ingredient has been the promotion of conservation of genetic resources as an integral part of the resource management strategy, through the establishment of the Mount Kulal biosphere reserve within the project study area. The biosphere reserve concept combines philosophy and action for a new dynamic approach to conservation. Intrinsic features of the approach are the zoning of reserves for multiple functions and the role of local populations as the active agents for conservation.

Sixth, field research has been closely linked with *in situ* training, demonstration and education. Exclosures have been built in order to demonstrate the impact of livestock on a site and the rate of vegetation recovery when they are excluded. Demonstrations of new fencing materials (e.g. bamboo) have been set up on a trial basis with a view to reducing human pressure on trees and shrubs. Meetings with elders (*barazas*) have

been organized frequently. As most of the pastoralists do not read or write, the project has been testing the most effective way of communicating land-use information to these people. In cooperation with the Kenya Ministry of Information and Broadcasting, a 15-minute radio programme is broadcast twice weekly in the Rendille language. Seminars are organized from time to time for planners, administrators and decision-makers. In-service training for field assistants and graduate study programmes with the University of Nairobi are among the other training programmes undertaken.

A number of logistic and organizational factors have also proven critical to the success of the project: partnership between institutions in tropical and temperate zones and international organizations such as UNEP and Unesco, with substantial funding from UNEP and more recently from the Federal Republic of Germany; presence of a permament core staff of research workers, supplemented by short-term visiting research workers from Nairobi and abroad; adequate facilities for field work such as headquarters (including laboratories and seminar rooms) linked to six field research and experimental stations distributed throughout the study area, field transport, experimental forestry plots, experimental livestock herds, etc.; links with countries sharing similar problems, as a basis for exchange of information; presence of a full time coordinator, to ensure integration and feedback among participants; close links with central and district government and with the local resource managers (i.e. the pastoralists of northern Kenya).

4.2 Training and institutional development

The capability to promote the integrated management of natural resources is closely tied to the availability of trained manpower. Recognition of this relationship has led many countries - particularly in the developing world - to accord priority to the question of trained endogenous manpower. This is seen as the key factor in enabling countries to adopt a new kind of economic development - one which stresses self-reliance and which allows countries to adopt authentically national policies for natural resources development and land management.

It is possible to recognize at least three major groups of problems, and associated causes, connected with the training of ecologists and other

specialists in various natural resources fields (e.g. forestry, agronomy, hydrology, etc.) in developing countries (27). The first major problem is a quantitative one. Most developing countries lack a critical mass of scientists - the term mass relating to both inadequate numbers of trained specialists and the general lack of mechanisms through which specialists can interact with each other. The second major group of problems concerns the type and quality of training that is undertaken by specialists from developing countries, which may not be attuned to the needs and conditions of those countries. The third group refers to the lack of continuity in much scientific endeavour in developing countries and to measures for promoting a favourable and stable environment for scientific activities.

A variety of actions can be developed to respond to these constraints. As illustration, mention might be made of some of the types of activities undertaken or sponsored by Unesco in the field of training and institution building. A first type is sponsorship of annual international post-graduate training courses in developed countries, designed to promote the training of specialists from developing countries in the methods and techniques of integrated survey, environmental research, land evaluation and resource management. Examples include a nine-month international post-graduate training course in integrated surveys at the Centre for Integrated Surveys, Enschede (Netherlands) and (a now terminated) ten-month international post-graduate training course in natural resources research and land evaluation at the University of Sheffield, United Kingdom.

A second, somewhat similar activity is the organization of similar courses in the developing countries themselves, designed to provide specialists trained in various disciplines and professional fields with experience of approaches of integrated resource management. An example here is the regular courses on integrated pastoral management in the Sahelian zone set up as a collaborative venture by Unesco, UNDP, UNSO and the Institut du Sahel. Specialists in agronomy, veterinary sciences, forestry, soil survey and hydrology are among those taking part in these nine-month postgraduate courses, which are held in conjunction with shorter, three-month courses for technicians. The aim of both types of activities includes the promotion of an interdisciplinary approach to resource management that harnesses the skills of people trained in particular specialties and places these within a broader resource use and land planning context.

A third type of training is that promoted through short term (e.g. one month), ad hoc courses in more specific fields. Examples here include courses in such topics as computer modelling for ecologists, use of remote sensing in land use planning, ecology of tropical forest ecosystems and watershed management. Wherever possible, such courses are organized at the sites of pilot research projects, thus basing the training on the findings and facilities of field research and on the resource management problems as perceived at the local level.

Fourth is the provision of individual study grants for training in integrated resource management and for exchange of information on research findings and methods. Study grants can be awarded for training of researchers and technicians from developing countries at specialized institutions in temperate zones and at the sites of field research projects in countries of the same ecological region sharing similar socio-economic and resource use problems. Study grants and reciprocal visits can also help promote understanding in particular fields. For example, in the South East Asia-Australasia regions, a programme of such visits has been started around the theme of forest structure and typology - a field where terminologies vary greatly from country to country, region to region (28). One desirable spin-off is the promotion of a common ecological language - an ecological lingua franca - that can transcend the differences between habitats that are widely separated culturally and geographically. Reciprocal visits using an agreed approach can help bridge the differences in terminologies, in facilitating consensus among research workers familiar with their own vegetation who are confronted by an unfamiliar landscape. And thus contribute in a small way to greater cohesion and understanding among ecologists and resource scientists from different countries.

A fifth type of action is support to institutions of research, training and demonstration in developing countries that seek to promote an integrated approach to resource management and land use. Examples include the setting up of the International Center for Tropical Ecology in Caracas and the International Center for Integrated Mountain Development in the Hindu Kush-Himalaya region in Kathmandu. The creation of institutions such as these can be facilitated by institutional links between developed and developing countries, and between the host government and international organizations such as Unesco. For example, the mountain institute in Kathmandu has been established following various agreements between Unesco and the governments of Nepal, Federal Republic of Germany and Switzerland, as well as of countries of the Hindu Kush-Himalaya region who are taking part in the work of the institute.

5. Conclusions and general recommendations

Integrated resource use is accorded high priority by many developing countries. Enhanced and sustained use of natural resources is seen as one of the keys to national economic development. Scientific research and cooperation can play a crucial role in helping countries towards strategies of sustained production - strategies which take account of the variability, complexity and uncertainty of natural resource problems and the need for action at local and national levels.

A fair amount of experience has been gained on approaches to integrated resource management. Many of the ingredients of successful projects are known, and range of methods and techniques are available. Groups of scientists in several Commonwealth countries have been at the forefront of recent scientific advances in this field, and this expertise might usefully be tapped in an expanded programme of scientific cooperation in the Commonwealth on integrated resources management.

In physiographic terms, it might be considered appropriate to give special attention to tropical islands and to coastal zone areas. Problems of resource allocation and use in these situations are of interest to many of the newly independent, developing countries of the Commonwealth. These are also zones where problems of reconciliation among conflicting land uses are particularly acute and where the scientific community can help planners in clarifying options in alternative resource strategies.

The principal aim of an expanded programme of scientific cooperation might be to increase the indigenous capacities of the smaller developing nations of the Commonwealth for integrated management of renewable natural resources, with special emphasis on coastal and island situations. Such a programme might include one or more of the following types of activity:

- multi-national support to about 3 pilot projects of applied research, training and demonstration, situated in the Caribbean, Indian Ocean and Pacific regions, each of 3-5 years duration, and planned and undertaken in liaison with existing networks of pilot research operations of other international programmes of scientific cooperation (eg the MAB Programme of Unesco);

- convening of short-term (e.g. 1 month) training courses in particular approaches to integrated resource management (e.g. adaptive environmenta management and assessment), based either at specialized institutions in developed countries (where the primary focus might be on the available methodologies as such) or at institutions or project sites in developing countries (where the primary focus might be on the application of methods and techniques to a particular resource problem);

- elaboration and testing of manuals and handbooks in particular methodological fields, specifically tailored to the needs and absorbtive capacities of groups of developing countries;

- provision of study grants for reciprocal exchange of individual scientists among institutions in Commonwealth countries at different stages of scientific development, as a means of promoting twinning arrangements and cooperative training programmes;

- support for reinforcement of existing research and training institutions in developing countries of the Commonwealth, to broaden existing mandates for integrated resource management.

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Coastal Zone Management: A Study Paper

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SUMMARY

Fifty-nine countries of the Commonwealth have sea coasts, and many are oceanic islands, archipelagoes, or heavily orientated towards extended coastlines.

A comparative study could identify commonalities of coastal type between Commonwealth countries, which would confirm or reject the feasibility of the focal projects suggested.

Coastal resources include materials and activities both on land and offshore within a distance of a few miles of the waterline. A wide range of industries, activities, and social uses of this space are listed, together with the related basic sciences. These are analysed in terms of the supporting services such as bathymetric surveying, coastal land surveys, remote sensing, geological surveying, and data and information management.

Scientific focal subjects identified include beach processes, coral reef biology, estuarine physics and chemistry, deltaic geology and sediment processes, ocean tides and sea levels, aquaculture, island arc tectonics, remote sensing, wave physics, wave energy, wave climate studies, mangrove biology, numerical modelling of coastal physical oceanography, oceanic island geophysics, physical/chemical and biological processes in lagoons, flood prediction and coastal defences, remote sensing of waves and real time wave forecasting, international oceanographic data exchange, marine parks and reserves, submerged karst geology, shelf-sea fronts, contributions to the World Climate Research Programme, coastal fisheries science, and waste disposal and pollution control studies.

Annexes of data are attached.

INTRODUCTION

Coastal zone science and management have been much discussed in the last 15 years. Following the rapid increase of exploitation of offshore petroleum in the 1960s; the steady rise in world fish catch during the 1960s; burgeoning tourism; and increasing awareness of pollution, it seemed logical that the technological and managerial lessons learnt from the exploitation of the continental shelf and its waters should be applied with even greater success in the more familiar coastal waters.

There have been frequent attempts at national and international levels to define the coastal zone, and to develop a coherent and logical discipline of coastal studies and coastal science. The concept of Coastal Zone Management was current in the mid-1970s, and was promoted by the United Nations Ocean Economics and Technology Bureau (OETB). The Scientific Committee for Oceanic Research (SCOR) of ICSU has recently been the scene of attempts to start a new international society of coastal science (Halifax, 1982). Several international journals now exist reporting scientific and engineering developments on the coast and continental shelf (Estuarine, Coastal and Shelf Science; Estuaries; Offshore Industry; Offshore Engineer; Ocean Industry; Oilman; Oceanologica Acta; Continental Shelf Science; etc.). Numerous meetings and symposia have been devoted to coastal science, and valuable report volumes produced (see FAO and UNESCO publications), and other UN Agencies have sponsored seminars and workshops. The Law of the Sea Convention has drawn attention to the rights of coastal states and the economic potential of the coastal zone.

In spite of all this activity it is fair to say that the effort to create a single coherent discipline has been a failure. Coastal environments are typified by intense variability in time and space, so that attempts to classify and generalise phenomena tend either to be hopelessly general and not useful, or so site-specific that they are only relevant to local problems. Economic and scientific activity have continued to increase in the coastal zones during the last decade, but any general systematic intellectual or methodological model is still lacking, and may be an impossible illusion.

Attempts to generate a theory of Coastal Zone Management tended also to collapse when faced with the great number of agencies and government departments at every level - local to national - which might be involved (e.g. Departments

of Interior, Planning, Transport, Shipping, Food and Fisheries, Conservation, Tourism, Local Government, Parks and Wildlife, Port Authorities, Safety and Health, etc.). Attempts by various United Nations Agencies to develop general principles as the guidance for aid and development programmes in CZM were further weakened because the legal and administrative divisions of responsibility between all the interested agencies differed so widely in each country.

In spite of these factors tending to prevent an orderly and coherent study of coastal economics, industry, and science, the truth remains that the coast is the most intensively used zone in most modern states (with a coast), and is therefore worthy of both investment and protection. The knowledge required to make this investment wisely is itself worthy of attention. The present paper will try to suggest some common factors amongst the Commonwealth Members which would justify cooperative research, but it must be recognised that a careful balance will be needed between the study of shared common factors, and the individual study of important local and essentially differing details.

The topics covered in the following sections will be:-

1) Classification of coastal nature of Commonwealth Member states
2) Summary of coastal resources
3) Summary of related scientific disciplines
4) Identification of subjects suitable for cooperation
5) Time-frames
6) Modalities
7) Benefits
8) Infrastructural requirements

CLASSIFICATION OF COASTAL NATURE OF COMMONWEALTH MEMBER STATES

The Commonwealth comprises 66 states and associated states, with a very high proportion of islands and coastal states. Only 7 member countries out of 47 are landlocked, and none of the 19 associated states are landlocked (see Annex 1A and 1B). Fifty nine countries (89%) therefore have a direct interest in coastal development.

Of the 40 member countries which are coastal or island in nature, 35 are in the Tropics, defined simply as lying wholly or largely between 30^{o} North and 30^{o} South of the Equator. Of the 19 associated states 17 are within the Tropics. Thus the science of coasts for Commonwealth countries becomes effectively the science of tropical coasts (the exceptions are UK, Canada, Cyprus, Malta, New Zealand, Bermuda, Falkland Islands, Gibraltar and Southern Australia).

A special class which tends to have a greatly increased length of coastline in relation to area comprises the archipelago states, of which there are 5 Member Countries (not including countries such as New Zealand or Trinidad and Tobago, where there are one or two large islands, and a number of very small off-lying islands). Amongst the associated states the distinction between a group of two or three islands and a scattered archipelago is more arbitrary, but probably only the British Virgin Islands and the Turks and Caicos can be classified as archipelagoes.

The variation in size and GNP of Commonwealth countries is of course enormous, but a very rough gauge of the importance of the coastline to the population can be derived by relating broad parameters to the coastline length (see Annex 1A and 1B).

Annex 2 plots the ratio of the coast length in kilometres to the square root of the area of each country, producing a dimensionless illustration of the importance of the coast to the country as a whole, or "Coastliness". The mean ratio is 10.5, and it is obvious that the distribution is very asymetrical. A large number of countries (33 = 72% of countries with coasts) have relatively short coastlines (ratios less than 10.5), whilst a relatively small number of countries have very long coastlines in ratio to their areas. The maximum ratios are for the Bahamas, Kiribati, Maldives, and Solomon Islands, all with ratios over 30. (See Annex 3).

Whilst it is common to plot the population density as population per unit area (included in Figures 1A and 1B), it is less common to show population per unit coast length (Annex 4). The most frequent ratio is 100-1000 people per kilometre of coast (19 countries). Only 4 countries have lower ratios (Bahamas, Kiribati, Solomon Islands, Falkland Islands). Three countries have over 50,000 people per kilometre of coast (Bangladesh, India, and Nigeria). These last 3 countries have the three greatest populations

in the Commonwealth, and also have very low "coastliness ratios" on account of their long landward borders, and relatively straight coasts.

Various systems have been proposed for the geographical/geological classification of coasts on a global scale (e.g. Johnson, 1919; Valentin, 1952; Sheppard, 1963; Inman and Nordstrom, 1971), based on the geomorphological features present, vegetation type, climate, or whether the coast is presumed to be emerging or subsiding into the sea. The system of Inman and Nordstrom is simple, though rather too broad for the present purposes. The classes proposed are:

- Mountainous coast
- Narrow continental shelf, hilly coast
- Narrow continental shelf, plains coast
- Wide continental shelf, plains coast
- Wide continental shelf, hilly coast
- Deltaic coast
- Reef coast
- Glaciated coast

These classes at least have the virtue of being simply appreciated.

Annex 5 lists some general characteristics of the coasts of Commonwealth countries, stressing again the variability. The tropical countries show all the range of Reef, Deltaic and Lagoon coasts, associated with both wide or narrow shelves, and mountainous or plain coasts. The temperate/polar countries exhibit a range of topographies, combined with glaciated and recently de-glaciated coasts. A problem with regard to cooperation and assistance is that the richer Commonwealth countries (UK, Canada, Australia, and New Zealand) are non-tropical (with the exception of parts of northern Australia), with mountainous and/or glaciated coasts. Thus they have very little indigenous experience of the environments which will be met in the less developed countries. Similarly, the variation between countries within the tropical zone is very great. Nevertheless, it would be possible to group together those countries sharing dominant coastal environments, particularly Coastal Reef, Deltaic, and Lagoonal. It would be a useful exercise to compile a detailed classification of coastal types in order to identify

truly comparable areas between which experience could be shared. Data may be available from FAO or UNESCO, if not within the Commonwealth system. Such a study should include a brief summary of climatic and vegetation factors: - Population density near the coasts, etc., sea temperature, and near-shore oceanographic conditions.

The discussion in terms of ratios should not conceal the importance of absolute magnitudes. The coast length of India is only twice that of the Bahamas, but it is twice as great. A 200 mile wide coastal zone (or other formula for deriving an Extended Economic Zone) will generate a much larger area for India because of its relatively straight coastline, than it will for Bahamas, with a convoluted coastline. Thus India is relatively richer in term of its offshore and continental shelf resources in proportion to its immediate coastal and nearshore resources; Bahamas has a very high immediate coastal resource, and proportionately less offshore. These and similar variations need to be evaluated in relation to national needs.

SUMMARY OF COASTAL RESOURCES

For the sake of simplicity the coastal zone will be deemed to include estuaries, lagoons, the beach itself, the land within a few miles of the shoreline, and the sea water and sea bed out to a distance of a few miles. The coastal zone does not include the whole continental shelf or EEZ. For the present purposes the Coastal Zone (CZ) is regarded as a scientific or management region including both some land and water, and is definitely not a legal or political unit.

Within Coastal Zones of various countries the following industries and resources are commonly exploited:-

- Beach sands for construction
- Heavy mineral sands in beaches and dunes
- Offshore sand and gravel for construction
- Land reclamation for building or farming
- Tourism and associated infrastructure, water sports and recreation

- Conservation and wildlife parks
- Commercial ports and terminals
- Fishing harbours
- Sea fisheries, and associated shore-based processing industries
- Shell fisheries, and associated shore-based processing industries
- Aquaculture, marine, estuarine, lagoonal
- Seaweed cropping or culture
- Coastal communications, roads, bridges, tunnels, island links
- Communications cables, electric power cables
- Oil and gas pipelines
- Power station and industrial water cooling inlets and outfalls
- Waste disposal by pipe or barge dumping
- Erosion prevention and beach stabilisation, dune stabilisation
- Dredging to remove navigational hazards
- Sea canals
- Artificial water enclosures, marinas, etc.
- Airfield runways
- Ship navigation services, buoys, lights, dredged channels, pilotage, etc.
- Meteorological and wave and current forecasting services
- Oil and gas exploration and production
- Desalination
- Salt pans and dissolved chemical recovery
- Pollution control
- Oil refineries, tanker farms
- Bulk ore processing, and other industries relying on sea transport
- Dams for tidal power generation (not common)

It is beyond the scope of the present paper to amplify the details of these industries or to indicate the interactions between them. Some of the activities are totally incompatible within the same area; whilst others are devoted to correcting side effects of other activities. Intensive multi-use of a coastal sea or estuary requires close control. Examples of studies of interacting systems are provided by the large estuaries in the USA, Chesapeake Bay, Pugett Sound, Delaware Bay, and the New York Apex Bight and Manhattan Bay; and by the Japanese management of the Inland Sea. In Europe there are examples of estuarine and coastal sea management in the regulation of activities in the Dover Straits, North Sea, Rhine Delta, and the Baltic.

The industries and activities listed above can generate employment, wealth, and social benefits such as improved health and recreation. Investment in scientific research to support these activities is desirable. States with similar environmental conditions could cooperate to solve scientific and technical problems related to the development of a given industry, or the control of pollution or erosion.

SUMMARY OF RELATED SCIENTIFIC AND TECHNICAL DISCIPLINES

The industries described above depend on a wide range of commercial and technical skills which will not be discussed here. The subjects which will be discussed include the basic sciences, plus the technical services which are often needed to conduct scientific observations in the field. Since the service activities are of potential benefits to all the sciences, they will be discussed first.

Technical service activities to support coastal science

(a) Bathymetric surveying and hydrography. Surveys for navigational charts of remote areas tend to concentrate on the shipping channels. Inventories of coastal resources will need improved maps, combining remote sensing images, with conventional inshore surveys at a detailed level. There is an excellent range of commercial systems available for this kind of bathymetric surveying and map plotting, and the equipment can be operated from small vessels.

(b) Beach, marsh, and lagoon surveying. These zones tend to receive reduced attention from both charts and land survey maps, both because of difficulty of access, and variability from year to year. Remote sensing, combined with conventional land surveys, and work in small boats, could be used to build up base maps of important wet-lands, beaches vulnerable to erosion or mining, lagoons suitable for cultivation or salt extraction, etc.

(c) Coastal oceanographic measurements. For many projects, scientific and commercial, there will be a need to measure oceanographic parameters such as wave height and period, current strengths, tidal and meteorological variations of sea level, water salinity and temperature, phytoplankton concentration, etc. The transfer of knowledge and skill in these activities would be an integral part of any programme of cooperative coastal science.

(d) Where coastal and offshore industries develop significantly there will often be a necessity for routine environmental measurement and prediction of coastal water conditions analagous to weather forecasts. This activity follows as a procedural formalisation of the activities in (c) above.

(e) Sedimentary and geological surveying (petroleum prospecting is excluded from this section). Many coastal and near-shore projects depend upon a sound scientific understanding of the nature of the sea floor, and its relation to sediment movements, and the effect on the neighbouring beaches. An improved programme of sediment sampling and mapping in coastal waters would provide important data in the long term for science and industry.

(f) Data and information services. The knowledge and data gained from coastal, estuarine, and lagoonal surveys needs to be published and available through local or regional publications and reports. These may be backed up by appropriate information or data centres, probably located in existing universities or research institutes. Such centres would provide data and information to research scientists and to government departments for planning purposes. Exchange of data between countries and regions would be facilitated by these centres.

(g) Basic sciences related to coastal research. The coast is by definition the region in which earth, air, and water intersect. Therefore all the physical processes of all three media can occur at the coast, plus all possible interactions between them. Additionally, estuaries, lagoons, and shallow coastal and continental shelf waters are the most biologically productive regions of the sea. Complex interactions occur when fresh river

waters laden with sediments in suspension and dilute solutions of minerals and humic acids mix with the sea water. There are changes in metal and salt ion speciation; ions are absorbed to clay and organic particles; previously separate particles may flocculate into large assemblages.

Plant and animal species which survive and prosper in the coastal zone may have to adapt to the varying salinity from normal sea water to fresh water within estuaries; whilst other species adjust to the variation between normal sea water and much higher salinities in lagoons and salt flats which may dry out in the sun. Yet other species accommodate the frequent exposure to the air on mudflats or foreshores as the tide retreats and advances again.

These simple points emphasise that almost all the processes of the environmental sciences - biological and physical - manifest themselves in extreme and complex forms in the coastal zone. This, combined with the innate local and regional variability of coasts, from tropical to arctic, makes it extremely difficult to identify unifying scientific themes. The following paragraphs indicate the relevant scientific subjects in a broad way, which would provide some guidance to relevant courses which could be taught at university undergraduate or technical college level.

(h) Geological processes. The nature of continental and oceanic rocks; plate tectonics; continental margins and coasts; beach processes; Quaternary changes of sea level; glaciations; coral reef growth through geological time; deltaic processes; coastal land forms; erosive coasts; sediment transport by rivers, estuaries, waves, and currents; wind transport and coastal dunes; geological processes of islands and archipelagoes; island arcs and vulcanism; gravity measurements in coastal seas.

(i) Physical oceanography. Air-sea interaction; winds, waves, and currents; estuarine processes and circulation; thermoclines and internal waves; upwelling; waves on beaches; extreme events, waves, storms, floods; combinations of extreme events; salinity and temperature of sea water and estuaries; mixing processes; fronts; deep ocean processes in the neighbourhood of oceanic islands; influence of the ocean on climate.

(j) Chemical oceanography. Chemical input of rivers; chemical processes in estuaries, and interactions with sediments; chemistry and biochemistry of lagoons and marshes; chemistry of intertidal sediments; nutrient cycling in coastal waters; oceanic marine chemistry in relation to oceanic islands; chemistry of contaminants and pollutants.

(k) Biology. Environmental biology of the terrestrial near-shore zone; stabilisation of the substrate by vegetation; productivity of the vegetation, and influence of salinity, drainage, groundwater level, etc.; productivity of marshes, wetlands, mangrove swamps, mudflats, etc.; seaweeds and intertidal algae; study of interstitial and microbial fauna, intertidal and subtidal; primary productivity of lagoonal, estuarine and coastal waters; zooplankton; study of shellfish and crustacea; fish biology and other macrofauna; coral biology and environmental biology of reefs; influence of environmental disturbances, thermal pollution, alterations of salinity, chemical or sewage pollution.

(l) Instrument science and engineering. Properties of sound in water and sediments and rock; design and use of acoustic instrumentation; use of electro-magnetic-based surface instruments - navigation, radar, range-finding, surveying, data telemetry; interpretation and enhancement of remote-sensed images and numerical data; use and maintenance of equipment such as current meters and wave-measuring buoys, temperature and salinity sensors; design, installation, and recovery of instruments placed on the sea bed or suspended in the water column; design of moorings; scientific and engineering work performed by divers; sediment and rock sampling equipment; meteorological instrumentation for use on buoys or offshore platforms.

(m) Social and economic sciences. Development and planning; social consequences of industrialisation; tourism and its impact; urbanisation of the coastal zone; conflicts of interest and use of coastal space; transport economics; economics of waste disposal and pollution; infrastructure requirements; study of educational, skill, and technical resources needed; sequential development of a coastal zone; legal regimes; international law of the sea convention.

The above notes cannot be regarded as exhaustive, but give an overview of the range of subjects relevant to coastal studies in different conditions. A peculiarity of the situation of many Commonwealth countries is that they are oceanic islands, and as a result their coast fronts directly onto the deep ocean with no extended coastal zone or continental shelf. In this context coastal oceanography becomes a special case of deep water oceanic oceanography.

IDENTIFICATION OF SUBJECTS SUITABLE FOR COOPERATION

Subjects suitable for cooperation should meet some or all of the following criteria:-

(a) The subject should be a key focus of modern scientific endeavour in the study of the coastal zone.

(b) The subject should be of maximum interest and maximum benefit to a large number of Commonwealth countries.

(c) The subject should be relevant to industries, activities, and social needs of Commonwealth countries.

The following subjects are suggested as worthy of further examination. After further perusal some subjects might be eliminated, and others added. The subjects are presented with supporting notes, illustrating the reasons for each choice. The inclusion of a subject on this list does not imply that no cooperative work is already under way. In some cases excellent cooperation or bilateral research programmes already exist. Where countries are mentioned as having specific expertise, this is as a result of the personal knowledge of the author of this paper; omissions certainly have been made, for which I apologise.

(1) Beach processes: Canada, UK, and Australia have very strong programmes of both scientific and engineering research. Scope for scientific aid and technical development. Singapore could be a useful centre.

(2) Coral reef biology: coral coasts dominate or are significant in 36 of the 66 Commonwealth countries.. Australia possesses the largest barrier reef in the world, and a major coral reef park and research organisation. Several major institutions are based at Townsville, Queensland.

(3) Estuarine physics and chemistry: many of the world's largest rivers are in Commonwealth countries:- Niger, Indus, Ganges, St. Lawrence, Fraser, Fly; and their estuaries or deltaic mouths are of enormous importance. The relevance of these studies links developed and developing countries.

(4) Deltaic geology and processes: the Niger, Indus, and Ganges sediment fans are amongst the largest in the world. The sedimentary processes and the petroleum potential are equally significant. Seismic, sidescan, and coring studies are all relevant.

(5) Ocean tides and sea level: recent study of the oceans, and the response of the oceans to astronomical and atmospheric forcing, depends upon knowledge of the variation in sea surface level at all periods from hours to decades. It has always proved extremely difficult to measure these variations far from the major continents and population centres. Some oceanic islands in the south Atlantic have been used. The principle could be extended to obtain data in other oceans.

(6) Aquaculture: farming of fish and shellfish in enclosed tanks or lagoons. This has been developed successfully by the Japanese, and in the Phillipines, as well as other countries of south east Asia. The French are investing heavily in aquaculture for the French Pacific islands. A similar programme would be relevant to the Commonwealth tropical islands and coastal states.

(7) Island arc tectonics: the Caribbean islands, Malaysia, Papua New Guinea, New Zealand, the Solomon Islands, and some other islands, are directly or closely associated with convergent plate boundaries and tectonically active subduction zones. Geophysical and geological study of these zones would provide a unifying theme for research on a global scale, and interest both developed and developing countries.

(8) Remote sensing - Coastal Zone Colour Scanner: many problems of coastal science in inaccessible environments, mangrove swamps, shallow reefs, marshes, glaciated areas, tundra, etc., could be approached by a combination of remote sensing and ground-truth studies. Techniques need improving in parallel with identification of key problems on the ground.

(9) Wave physics, wave energy, wave climate: Australia, Canada, and UK have advanced wave research programmes, and well developed national or state data banks. These techniques could be transferred to most Commonwealth coastal countries with benefit to coastal defences, and improvements of offshore coastal structure design, and forecasting of extreme wave conditions.

(10) Mangrove biology: this is already a developed international subject in south east Asia, and with extensive cooperation promoted by UNESCO. There may be scope for specific Commonwealth programmes.

(11) Numerical modelling of coastal processes: advanced numerical models have been developed for such processes as storm surges, wave propagation, tidal amplitudes and currents, mixing and front formation, estuarine circulation, etc. These models are usually specific to a given coastal sea or estuary. Cooperative studies might identify those features of the models which could be transferred to other regions. Adoption of modelling techniques early in the "learning curve" of coastal research might save very large sums of money which would otherwise be spent on many years of field observations, or expensive hydraulic models.

(12) Oceanic island geophysics: oceanic islands, whether coral atolls or volcanic, are usually related to past events at plate tectonic spreading centres, since the coral is presumably based on an underlying seamount. A great deal has been learnt about the spreading chronology from the Deep Sea Drilling Project, but the study of the geology and geophysics of oceanic islands and the surrounding sea bed could add significant new data, especially in respect of the cooling of the mid-ocean ridges.

(13) Lagoons - physical and chemical processes: tropical coasts are rich in shallow lagoons associated with deltas, swamps, barrier beaches, etc. These lagoons are subject to extreme variations in temperature, water supply, and possibly salinity, as well as reacting to meteorological forcing. Diurnal, seasonal, and inter-annual variations need to be much better understood. Work on these subjects has been promoted by UNESCO.

(14) Lagoons - biological productivity: following from (13) the natural productivity of lagoons needs further study, with special attention to the potential for artificial increase of food production.

(15) Flood prediction and coastal defences: extreme storm conditions associated with meteorological forcing of sea level can cause violent flooding, as has occurred in Bangladesh and UK. Numerical models have been developed for forecasting such floods. The technique could be extended to other areas where floods are serious, if less notorious.

(16) Remote sensing of waves, and the WMO Wave Programme: by the end of the decade several satellites may be in orbit measuring wave parameters. "Sea truth" data will be needed, and this will be especially difficult to obtain away from Europe and North America. Islands - or other near-shore locations - could be identified where wave monitoring would contribute the greatest value globally. WMO is developing a worldwide programme in improvement of wave monitoring and coastal forecasting. Commonwealth countries could participate as actively as possible.

(17) International Oceanographic Data Exchange: The Intergovernmental Oceanographic Commission promotes International Oceanographic Data Exchange (IODE), and this is also encouraged by the Law of the Sea Convention. Developing countries are urged to cooperate in the collection, storage, and exchange of data. In general, the most developed technical states have the most developed oceanographic data banks. In the present context data on coastal seas and estuaries is as important, or more important, than open ocean data, but is likely to be stored in the same types of data centres. Countries such as India and Pakistan have already started to develop National Oceanographic Data Centres, and regional or cooperative centres could be encouraged in other parts of the Commonwealth.

(18) Parks and reserves: rising standards of living, tourism, and industrial development are likely to result in coasts becoming increasingly built up and polluted. Since the coastal zone is a narrow strip only a few miles wide, it is possible for the natural state to be completely destroyed. All Commonwealth countries should be encouraged to identify substantial sectors of their coastal zones which should be protected in perpetuity from industrial development, and to apply scientific methods to the development of management codes for other areas where exploitation should be limited.

(19) Limestone geology, karst, and submarine springs: limestone platforms such as those of the Bahamas, coral reef growth on the geological timescale, coastal and submarine karstic features, and the upwelling of fresh water offshore are loosely related subjects which would benefit from further research in tropical waters. Where there is a shortage of potable water onshore, it may be possible to locate and exploit submarine springs.

(20) Shelf-sea fronts: where a country has a substantial continental shelf, the regions of mixed and stratified water in the near-shore zone meet at fronts. The position of fronts affects primary productivity and fisheries. Increased study of these phenomena would probably be beneficial for those countries with continental coasts such as Guyana, Nigeria, Ghana, India, etc.

(21) World Climate Research Programme: the oceanographic component of the WCRP is placing a heavy emphasis on tropical ocean interaction with the atmosphere. Whilst the design of the science programmes is oriented towards open ocean phenomena, these programmes may require a network of base stations, satellite communication stations, data gathering centres, etc. As always, there are problems with obtaining even coverage away from the developed continental nations. Commonwealth coastal states and islands in the Tropics might be able to provide facilities. They would probably gain extensively by the transfer of skills and scientific knowledge in the process.

(22) Coastal fisheries science: the science and technology of fisheries is highly developed, and extensive aid programmes are run by FAO. There may be scope for increased Commonwealth cooperation in the study of primary productivity, fisheries dynamics, and the promotion of increased fish populations.

(23) Waste disposal and pollution control: there are numerous scientific problems associated with the acceptable and unacceptable limits of waste disposal in coastal seas. These require study of currents and waves, seasonal variations, sediment properties, dispersal of river plumes, etc. The general techniques are probably transferrable, although specific solutions depend upon the measurement of large quantities of local data and/or numerical modelling. A good basis of knowledge already exists in several Commonwealth countries, including UK, Canada, India, Australia, and New Zealand.

NOTE: Topics related to offshore oil and gas, and to bedrock mining, have been omitted. Practice of these industries and the related engineering in the coastal zone is identical either with practice on land, or in the offshore zone 10-100 miles offshore. No special scientific problems are raised by trying to work in the coastal zone.

TIME FRAMES

The time frame for a cooperative programme on any of the topics mentioned above depends upon so many variables that it is not practical to suggest any firm figures here. Two to five year programmes would in many cases produce very effective benefits. The choice of time scale will depend upon the degree of knowledge and skills already existing and relevant in the cooperating region; balance of education/pure science/ applied science/economic development envisaged; and financial commitment. The choice of timescale seems to be more a matter of financial and political commitment than scientific necessity.

MODALITIES

Basic sciences related to coastal research

Increasing the number of qualified personnel and technicians working in the coastal sciences and industries depends upon long term commitments to educational programmes. Annex 6 lists those institutions which have been identified as having an existing marine science programme, or those teaching subjects which probably have a marine element. Exchange programmes of lecturers; exchange of students; the development of information and data services; publication of new journals or newsletters, would all be relevant.

Focal projects

For each of the focal topics listed above it is possible to envisage both collaborative research projects, training of personnel, and transfer of data and information. The balance of these activities would depend upon the range of countries involved, timescale, and political, social and economic objectives.

Whilst it is tempting to suggest that these decisions should be left to ad hoc, evolutionary, procedures, it would be possible to devise a general framework within which a proportion of resources were committed in principle to the different activities.

BENEFITS

In the section above entitled "Summary of Coastal Resources", the potential economic and social benefits were used as the basis from which relevant scientific fields were derived.

Taking into account the very high proportion of Commonwealth countries with extended coastlines; the commonality of tropical locations; the broad range of industries and activities which prosper in proximity to the sea; and the scientific interest in trying to develop a coherent synthesis of coastal sciences; the benefits of cooperative research and education in coastal sciences are considerable. However, emphasis on coastal science will always require the support of a range of loosely linked projects, or even totally independent projects, and it is highly improbable that a theme would ever emerge with the dramatic appeal of space research, high-energy physics, or biophysics.

INFRASTRUCTURAL REQUIREMENTS

A total analysis of these requirements is not possible in the present brief report. Annex 6 lists the institutions so far identified as having relevant facilities. Marine sciences generally require a high level of competence in basic physical or biological sciences at university level, combined with practical ability and a willingness to work out-doors or at sea in arduous conditions. It needs emphasising that impressionable young people who are enthused by environmental idealism or television films of the sea, often abandon their goals when they find out how hard marine science is both intellectually and physically. Educational programmes should aim to develop the primary sciences to the highest level possible, whilst providing optional courses in marine topics and practical applications.

It is important that the balance of courses should include the topics of instrument engineering, electronics, and offshore engineering, if the investment in science is to lead to economic exploitation.

Much of the scientific work envisaged in the listing of focal topics can be conducted without substantial research vessels. Many of the projects would be conducted from beaches or in estuaries or lagoons where small motor launches would be sufficient. Other projects require only the installation of instruments or recorders in shallow water. Some of the projects requiring more sea-going time (for example, (2), (4), (7), (12), (20), and (22)) would probably require vessels of 20-30 m length. Since the vessels required are usually small, the projects are not dependent upon sophisticated harbour facilities, or large marine research institutions with specially dedicated docks.

Most of the projects would benefit from taking a modern approach to data gathering and data management. Wherever possible, researchers should be trained to use modern instrumentation, and to store and process it digitally. This is a recommendation of perfection. If experience shows that digital instruments cannot be maintained in working order in the climatic and environmental conditions encountered, then reliance must be placed on simpler instruments and recording methods.

Notwithstanding the possible benefits of using high technology methods, many of the problems listed as focal topics imply labour intensive solutions. Because data have to be gathered over long periods and from inaccessible locations, there will be a premium on local knowledge, skill at traversing difficult terrain, etc. Locally trained staff at the technician level could thus be very important.

Where small populations on remote islands are without indiginous university or research institutional facilities, regional groups could be established whereby the different countries contributed different resources to the common programme.

SUMMARY AND CONCLUSIONS

Coastal science is of interest to the great majority of Commonwealth countries, and all countries with a sea coast could benefit economically and socially from increased investment and cooperation. Unlike space research or high energy physics, every country, at every stage of economic development, can participate in coastal research at least to a limited extent, and benefit from it.

COASTAL PARAMETERS AND RATIOS FOR COMMONWEALTH MEMBERS

ANNEXE 1A

Name	$30^{o}N$ $30^{o}S$	Land Locked	Area km^2=A	Coast Length km=L	Population	$\frac{P}{A}$	$\frac{P}{L}$	$\frac{L}{\sqrt{A}}$	Archi-pelago	$\frac{GNP}{CAPITA}$ US$
Antigua + Barbuda	✓		441	153	100,000	226.7	653.9	7.28		1,550
Australia	+/-		7,686,848	25,760	14,500,000	1.9	562.88	9.29		11,080
Bahamas	✓		13,935	3,542	241,000	14.3	68.04	30.0	✓	3,620
Bangladesh	✓		143,998	580	88,513,000	629.8	152,608.62	1.52		140
Barbados	✓		430	97	249,000	696.0	2,567.01	4.67		3,500
Belize	✓		22,963	386	145,000	4.3	375.64	2.54		1,080
Botswana	✓		600,372		800,000	1.4				1,010
Britain			244,046	12,429	55,900,000	229.4	4,497.54	25.15		9,110
Canada			9,976,139	90,908	24,343,181	2.4	267.77	28.78	✓	11,400
Cyprus			9,251	537	620,000	64.8	1,154.56	5.58		3,740
Dominica	✓		751	148	83,000	133.1	560.81	5.40		750
Fiji	✓		18,272	1,129	630,000	32.8	558.01	8.35		2,000
Gambia	✓		11,295	80	603,000	53.1	7,537.50	0.75		370
Ghana	✓		238,537	539	11,679,000	49.4	21,667.90	1.10		400
Grenada	✓		344	121	110,000	290.1	909.09	6.52		850
Guyana	✓		214,969	459	793,600	3.7	1,728.97	0.98		720
India	✓		3,287,782	7,003	685,184,692	209.9	97,841.59	3.86		260
Jamaica	✓		10,991	1,022	2,188,000	200.1	2,140.90	9.74		1,180
Kenya	✓		582,646	536	15,865,000	29.8	29,598.88	0.70		420
Kiribati	✓		886	1,143	59,000	66.5	51.61	38.40		N/A
Lesotho	✓	✓	30,355	x	1,341,000	46.1				540
Malawi	✓	✓	118,484	x	5,951,000	52.3				200
Malaysia	✓		329,749	4,675	13,900,000	43.0	2,973.26	8.14		1,840

Name	$30^{o}N$ - $30^{o}S$	Land Locked	Area km^2=A	Coast Length km=L	Population	$\frac{P}{A}$	$\frac{P}{L}$	$\frac{L}{\sqrt{A}}$	Archi-pelago	$\frac{GNP}{CAPITA}$ US$
Maldives	✓		298	644	154,000	666.6	239.13	37.31		N/A
Malta			316	140	343,000	1,265.8	2,450	7.87	✓	3,600
Mauritius	✓		1,865	177	958,000	482.5	5,412.42	4.09		1,270
Nauru	✓		21	24	7,254	380.9	302.25	5.23		N/A
New Zealand			268,676	15,134	3,300,000	12.2	218.05	29.20		7,700
Nigeria	✓		923,768	853	84,732,000	94.1	99,334.11	0.88		870
Papua New Guinea	✓		461,691	5,152	3,007,000	6.7	583.65	7.58		840
St. Lucia	✓		616	158	124,000	162.3	784.81	6.36		970
St. Vincent + Grenadines	✓		338	84	107,000	257.7	1,273.80	4.26		630
Seychelles	✓		280	491	66,000	357.1	134.41	29.34	✓	1,800
Sierra Leone	✓		71,740	402	3,474,000	50.1	8,641.79	1.50		320
Singapore	✓		581	193	2,400,000	4,130.8	12,430.00	8.0		5,240
Solomon Is	✓		28,446	5,313	229,000	7.0	43.10	31.50	✓	640
Sri Lanka	✓		65,610	1,340	14,815,000	228.6	11,055.97	5.23		300
Swaziland	✓	✓	17,363	x	557,000	34.5				760
Tanzania	✓		945,087	1,424	18,141,000	20.1	12,739.46	1.46		280
Tonga	✓		699	419	97,000	1.3	231.50	15.85		N/A
Trinidad+Tobago	✓		5,128	362	1,168,000	234.0	3,226.51	5.05		5,670
Tuvalu	✓		28	24	8,000	285.7	333.33	4.53		N/A
Uganda	✓	✓	236,036	x	13,201,000	55.0				220
Vanuata	✓		14,763	x	117,000	6.7				350
Western Samoa	✓		2,842	403	157,000	70.3	309.00	7.55		N/A
Zambia	✓	✓	752,614	x	5,766,000	7.7				600
Zimbabwe	✓	✓	390,580	x	7,600,000	18.4				870

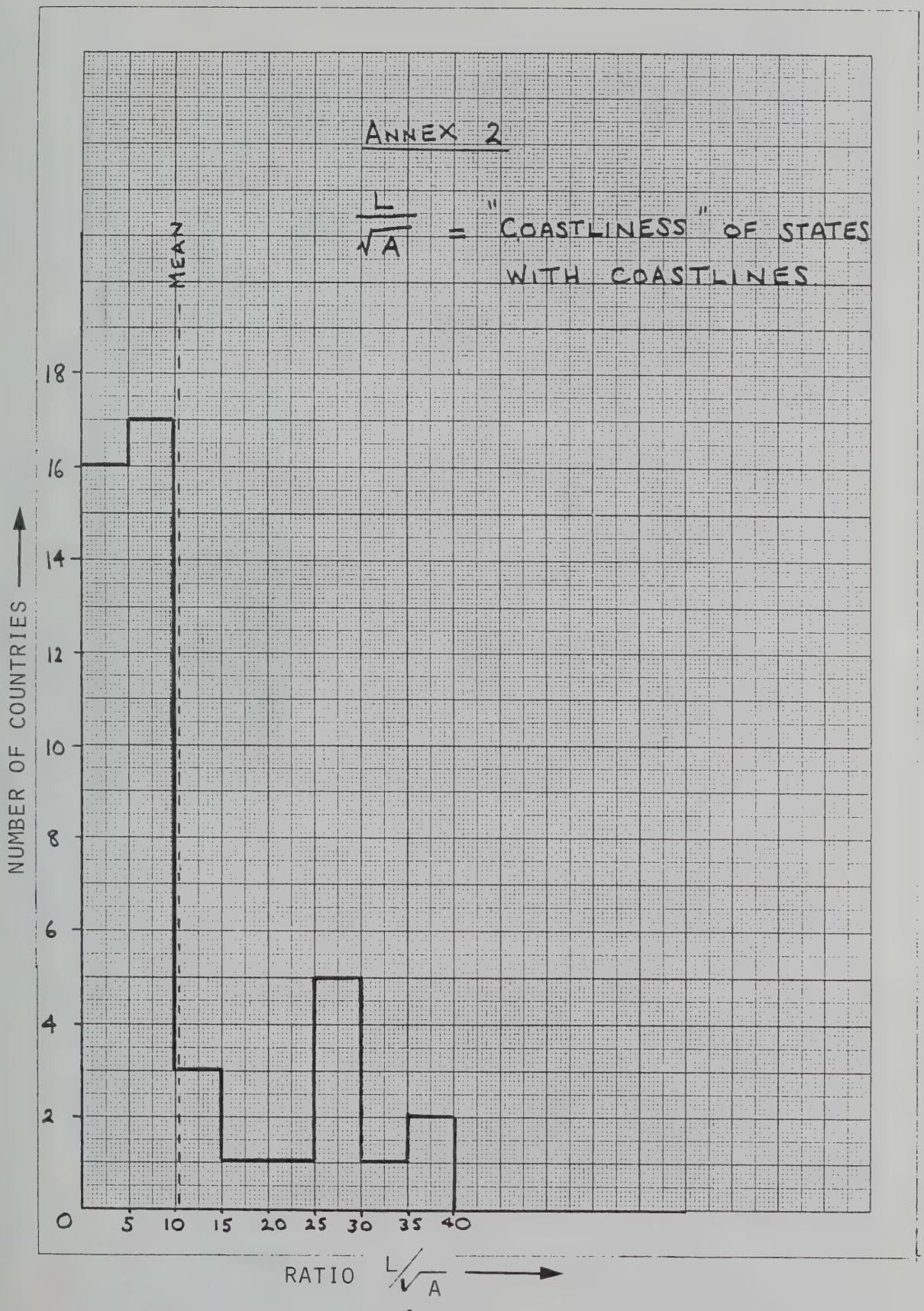
COASTAL PARAMETERS AND RATIOS FOR ASSOCIATED STATES

ANNEX 1B

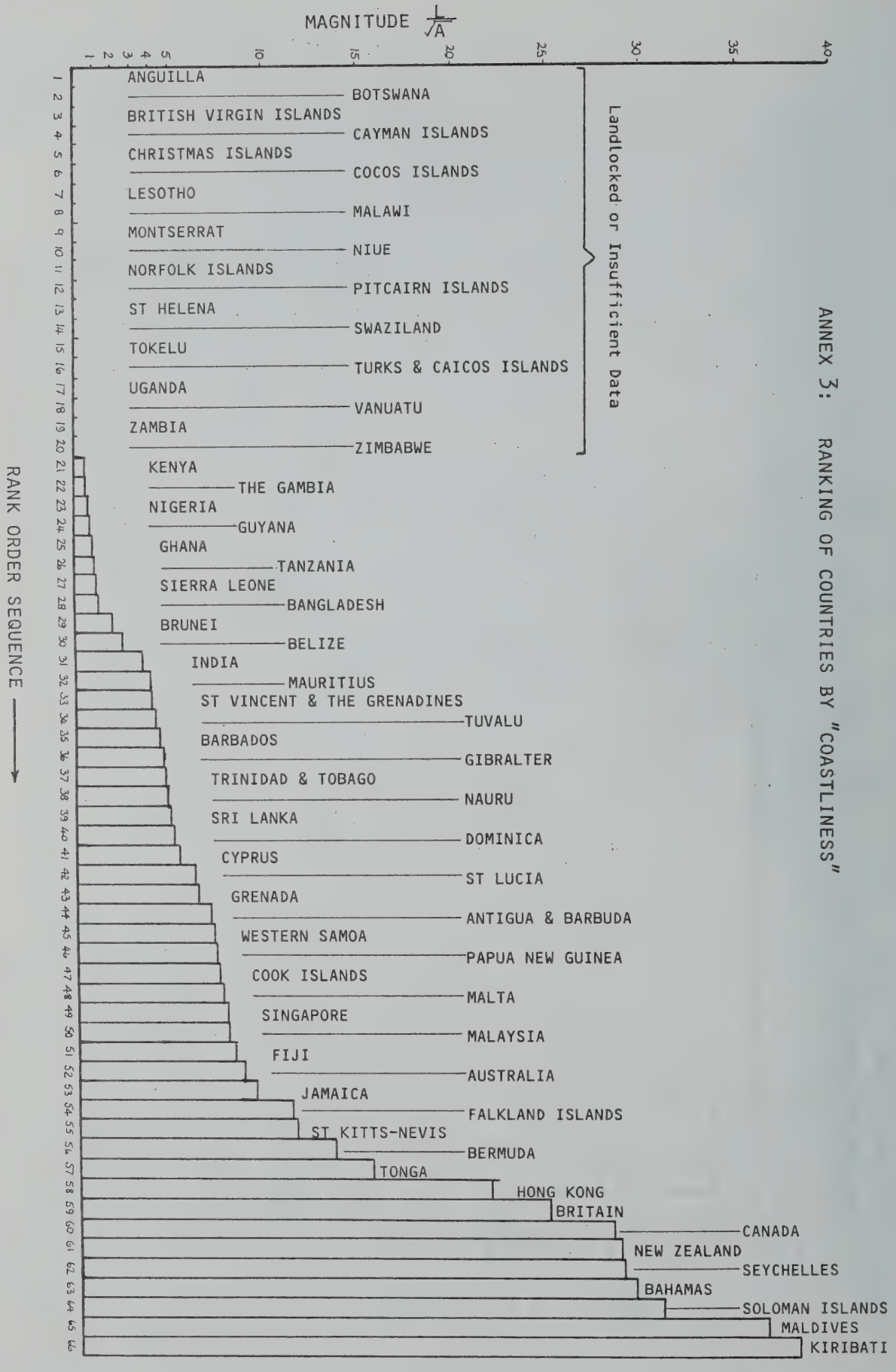
Name	$30^{o}N$ $30^{o}S$	Land Locked	Area km^2=A	Coast Length	Population	$\frac{P}{A}$	$\frac{P}{L}$	$\frac{L}{\sqrt{A}}$	Archi-pelago	GNP CAPITA US$
Anguilla	✓		90.6	-	6,500	71.74	-	-		-
Bermuda			53	103	59,000	1,113.20	572.81	14.14		9,440
British Virgin Islands	✓		153	-	12,500	81.69	-	-	✓	-
Brunei	✓		5,765	161	220,000	38.16	1,366.45	2.12		11,890
Cayman Islands	✓		259	-	17,340	66.94	-	-		-
Christmas Is	✓		135	-	3,184	23.58	-	-		-
Cocos Islands	✓		14		487	34.78	-	-		-
Cook Islands	✓		234	120	18,200	77.77	151.66	7.84		-
Falkland Is			12,173	1,288	1,890	0.15	1.46	11.67		-
Gibraltar			6.5	12	29,600	4,553.84	2,466.66	4.72		4,320
Hong Kong	✓		1,060.18	733	5,147,000	4,854.83	7,021.82	22.51		4,210
Monserrat	✓		102.3	-	12,074	118.02	-	-		-
Niue	✓		259	-	3,600	13.89	-	-		-
Norfolk Is	✓		34.5	-	2,180	63.18	-	-		-
Pitcarn Is	✓			-	70	-	-	-		-
St. Helena	✓		121.73	-	5,216	42.84	-	-		-
* St. Kitts-Nevis	✓		261.6	193**	50,000	191.13	259.06	11.93		920
Tokelu	✓		10	-	1,600	160	-	-		-
Turks + Caicos	✓		499	-	7,400	14.82			✓	

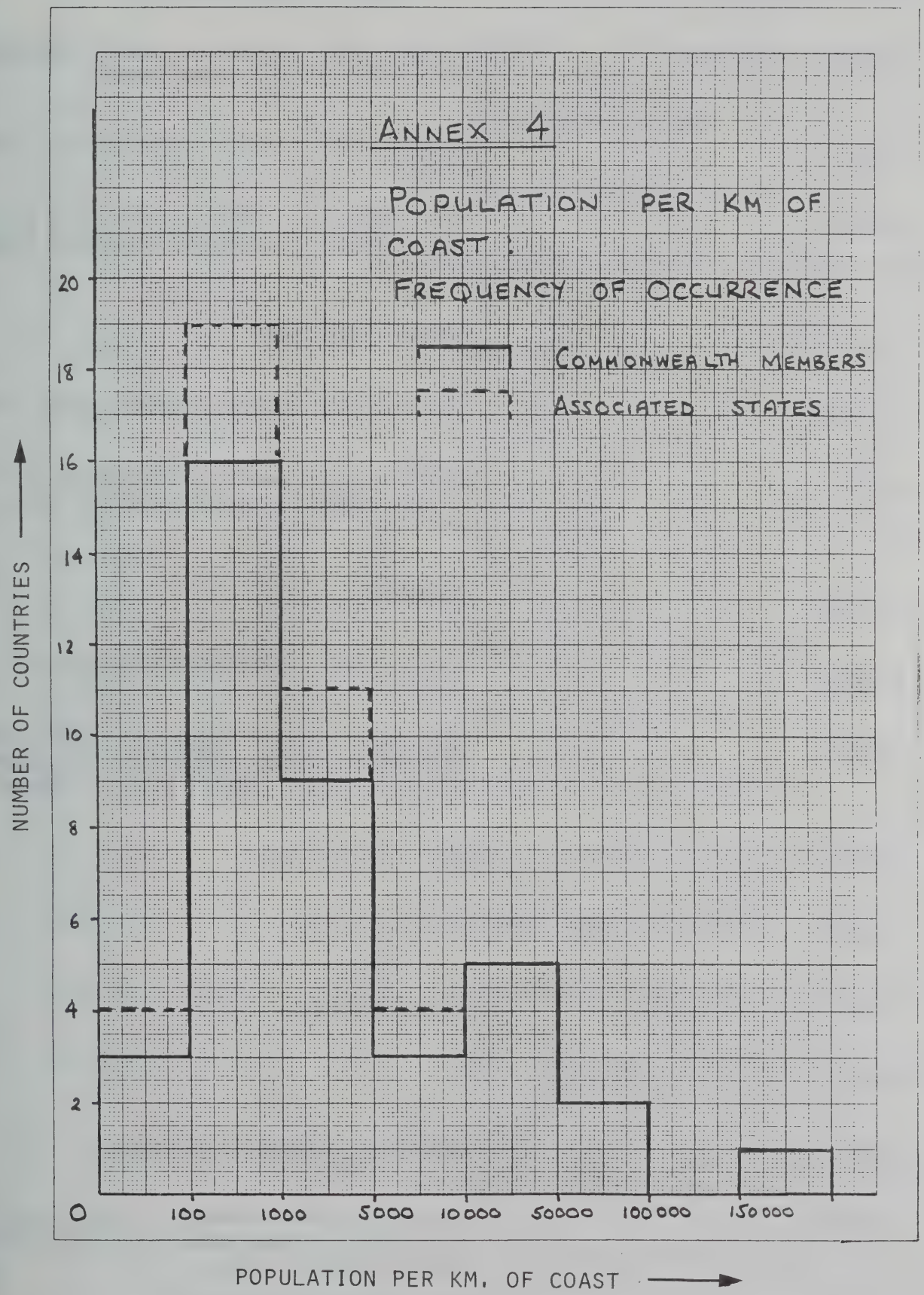
* As of 19th September 1983 St. Kitts'Nevis became 48th Commonwealth member

** Including Anguilla


ANNEX 2
$\frac{L}{\sqrt{A}}$ = "COASTLINESS" OF STATES WITH COASTLINES.
MEAN
NUMBER OF COUNTRIES
18
16
14
12
10
8
6
4
2
0
5
10
15
20
25
30
35
40
RATIO $\frac{L}{\sqrt{A}}$

ANNEX 3: RANKING OF COUNTRIES BY "COASTLINESS"




ANNEX 4
POPULATION PER KM OF COAST :
FREQUENCY OF OCCURRENCE
COMMONWEALTH MEMBERS
ASSOCIATED STATES
NUMBER OF COUNTRIES
0
2
4
6
8
10
12
14
16
18
20
100
1000
5000
10000
50000
100000
150000
POPULATION PER KM. OF COAST

MEMBER COUNTRIES	COASTAL CHARACTERISTICS
Antigua and Barbuda	Volcanic rock, mostly low lying, limestone, large lagoon to W., sandy beaches
Australia	Hilly, cliffs, tropical to temperate, broad shelf
Bahamas	Coral limestone islands usually long and narrow rising to low ridge backed by lagoons and swamp
Bangladesh	Deltaic coastline
Barbados	Limestone and submerged barrier reefs offsho
Belize	Shallow coastal waters of Caribbean to S and E, dotted with islands bounded by large cora reef
Botswana	Landlocked
Britain	Hilly, cliffs, rocky and sandy beaches
Canada	Vast ocean inlet of Hudson Bay, sea access to most of Arctic archipelago, restricted because of ice - coastal plain v. low relief
Cyprus	Rocky with beaches
Dominica	Cliffs in south
Fiji	Volcanic origin
Gambia	?
Ghana	Coastline on Atlantic to south
Grenada	Volcanic island, strongly cliffed especiall on W side; S coast more gentle dissected into 20 drowned valleys
Guyana	Flat, deltaic coastal plain

MEMBER COUNTRIES	COASTAL CHARACTERISTICS
India	Varied
Jamaica	Many bays and harbours
Kenya	Indian Ocean coastline
Kiribati	Coral atolls formed on submerged volcanic chain
Lesotho	Landlocked
Matawi	Landlocked
Malaysia	Complex
Maldives	Coral
Malta	Limestone cliffs and sandy bays
Mauritius	Encircled by coral reef
Nauru	Coral atoll in Central Pacific
New Zealand	Complex, mountainous, partly glaciated
Nigeria	Mangrove swamps on coast
Papua New Guinea	S covered by swamps, more mountainous to N
St. Lucia	Coral reefs, delta plain filling a drowned valley embayment on W coast
St. Vincent & The Grenadines	Volcanic island, W coast steeply cliffed, E coast gentler, narrow coastal plain to the N
Seychelles	Coralline group of flat coral islands
Sierra Leone	Hilly coastline

MEMBER COUNTRIES	COASTAL CHARACTERISTICS
Singapore	Low lying
Solomon Islands	Volcanic
Sri Lanka	Land slopes to sea in terraces
Swaziland	Landlocked
Tanzania	E African seaboard, bounded by Indian Ocean on E.
Tonga	169 islands in SW Pacific, E islands coral formation, islands to W - volcanic
Trinidad & Tobago	Narrow mountain ranges follow N and S coasts
Tuvalu	9 coral atolls in SW Pacific
Uganda	Landlocked
Vanuatu	Narrow coastal strips of cultivated land
Western Samoa	Surrounded by coral reefs
Zambia	Landlocked
Zimbabwe	Landlocked
ASSOCIATED STATES & DEPENDENCIES	
Anguilla	Flat coralline island
Bermuda	Coasts dotted with sandy bays, coves and craggy cliffs
British Virgin Islands	Steep, thickly wooded with coral reefs, coves and beaches

ASSOCIATED STATES & DEPENDENCIES	COASTAL CHARACTERISTICS
Brunei	Swampy coastal plain - much of coastal area covered in dense equatorial forest
Cayman Islands	Rock bound coasts protected by coral reefs enclosing a few anchorages
Christmas Islands	Central plateau descending to sea in steep slopes and terraces
Cocos Islands	2 separate atolls of 27 coral islands, islands surround lagoon with difficult anchorage
Cook Islands	N Cooks are atolls, A Cooks volcanic
Falkland Islands	Deeply indented coastlines, good anchorages
Gibraltar	High vertical cliffs
Hong Kong	Land surrounding harbour reclaimed from sea
Monserrat	Volcanic mountainous island
Niue	Coral island in S. Pacific
Norfolk Island	Land slopes down to sea at Sydney Bay in S, coastline chiefly cliffs
Pitcaim Islands	Rugged landscape, access from sea difficult
St. Helena	Volcanic and mountainous
St. Kitts-Nevis	?
Tokelau	3 atolls, coral islets surround central lagoon
Turks & Caicos Islands	Mainly flat

INSTITUTIONS WITH MARINE SUBJECTS

1. University of Agriculture, Malaysia
Division of Fisheries and Marine Science
- Aquatic Microbiology

3. University of Agriculture, Malaysia
Division of Fisheries and Marine Sciences
- Biology and Taxonomy of Fishes

5. University of Agriculture, Malaysia
Division of Fisheries and Marine Sciences
- Fish Culture

10. University of Agriculture, Malaysia
Division of Fisheries and Marine Sciences
- Nutrition of Fishes

74. University of Hong Kong
Department of Zoology
- ecological parasitology, esp. of freshwater and marine fishes

86. University of Ife, Nigeria
Department of Biology
- Fish and fisheries management

627b. University of Roorkee
Department of Civil Engineering
-Offshore structures

629. University of Singapore
Department of Civil Engineering
- coastal engineering

638. University of Singapore
Department of Civil Engineering
- lime stabilisation of marine clay

650. University of Singapore
Department of Civil Engineering
- surge tank studies

739. Indian Institute of Technology, Kuaragpur
Department of Naval Architecture
- ship resistance, structures, design, etc.

945. Annamalai University, India
Department of Marine Biology

956. Bhopal Vishwavidyalaya, India
School of Biological Sciences

959. University of Cochin, India
Department of Marine Sciences

960. University of Dar Es Salaam
Department of Zoology and Marine Biology

1005. Konkan Krishi Vidyapeeth
+1006 Faculty of Fisheries, Marine Biological Research Station

1013. University of Lagos
Department of Biological Sciences
- fisheries biology and marine ecology

1018. University of Madrass
Department of Botany
- marine algae

1031. Makerere University
Department of Zoology
- fish biology

1033. University of Malawi
Department of Biology
- nutrition of fishes

1068. University of Poona, India
Department of Botany
- marine hydrobiology

1094. University of Science, Malaysia
School of Biological Sciences
- ecology of mangroves and coral reefs

1097 - fish biology

1098 - fish population dynamics

1105. Shivaji University
Department of Botany
- photosynthesis in marine environment

1107. University of Singapore
Department of Zoology
- ecology and taxonomy of mangroves and coral reefs

1112. South Gujurat University
Department of Bioscience
- fisheries science

1114. University of South Pacific
School of Natural Resources
- marine biology

1127. University of Sri Lanka
Department of Botany
- seaweeds

1132. University of the West Indies
Department of Zoology
- marine biology

1173. University of Lagos
Department of Chemistry
- marine chemistry

1236. Papua New Guinea
University of Technology
Department of Fisheries

1278. University of Science, Malaysia
School of Physics
- exploration geophysics, offshore surveys

1342. University of Nigeria
Department of Mathematics
- wave propagation

Coastal Zone Management - A Field for Scientific Cooperation in the Commonwealth

I L Baumgart - New Zealand

"The ocean is not an isolator. People are separated by mountains, jungles, glaciers and deserts, but are connected by oceans." - Thor Heyerdahl.

1. The importance of the coastal zone

70% of the world's people live within 80kms of the coast, and it is in the coastal zones that human beings put the greatest pressure on the marine environment. Of the 48 countries who are members of the Commonwealth and the 18 who are associated states and dependencies, only 7 are landlocked without any coastal zone. Hence that most productive and most delicately balanced unit of the environment - the sea/land interface - is an area of common interest throughout most of the Commonwealth.

The importance of the coastal zone to the life of the people varies according to the wide range of geographic types of Commonwealth countries. On the small islands in the large oceans - the coral atolls and the small reef-fringed volcanic islands so common in countries of the South Pacific, the Indian Ocean, and the Caribbean - the whole life system is dependent on the coastal zone. Food gathering is from the reef and lagoon; waste disposal is into the lagoon, transport is mostly by canoe across the lagoon, and social and cultural activities are on the edge of the lagoon. Without a hinterland the community is completely dependent on the health and productivity of the coastal zone for its own health and survival, and customs and codes of conduct have been built into traditions to safeguard the process. Land tenure systems recognise the importance and coherence of the coastal zone by extending customary ownership seaward as well as landward from the shoreline.

On larger islands where there is a hinterland as well as a coastal zone, the biggest concentrations of people are at the coast. The coastal and inland communities develop distinct but complementary roles. The coastal people depend largely on the production of the land of the coastal fringe, and of the reef, lagoon, and estuary systems of the coastal waters. The inland people may take no direct part in coastal zone activities, but rely on it through trade for products of the coastal zone such as fruit, fish and salt and for transport through coastal waters. They may indirectly influence the health and productivity of the coastal zone by their land use and waste disposal practices in upper reaches of the rivers.

In larger land masses in which the coastal zone is only a small proportion of the total land area, and in countries largely bounded by frontiers on land, the coastal zone is relatively less important, though it still provides a source of protein, a repository for industrial and domestic wastes, and a means of transport for exports and imports. There is however an increased recognition of its importance with the international acceptance of Extended Economic Zones. Some countries under heavy population pressure and with limited land-based resources see their EEZ as providing potential opportunities for substantially increasing the primary production of their nation.

2. Coastal interests generate cooperation

The usual situation is for many countries to border the same sea, but for none to have exclusive rights of ownership to it beyond territorial limits. The bordering countries therefore readily regard it as "our sea", and active cooepration in its management is engendered, even in groups of countries with land-based

tensions and open conflicts. For example, active cooperation is currently continuing in the management of the waters of the Eastern Mediterranean and in the Kuwait Seas Programme of the Gulf Countries in spite of political differences and hostilities.

Commonwealth countries are actively involved in most of these international cooperative programmes, and the scale to which they have committed themselves gives an indication of the importance countries attach to the management of their coastal zones.

Since the International Council for the Exploration of the Sea (ICES) was established in 1902 there have been many regional and international institutions and forums for cooperation in studies of the marine and coastal environment. ICES is active primarily in the North Atlantic and Baltic Seas, and in 1967 initiated the first major cooperative investigation into marine pollution by substances harmful to fisheries being discharged, or likely to be discharged, into the North Sea and adjacent seas. In 1960 UNESCO established the Intergovernmental Oceanographic Commission (IOC) to promote, plan and execute marine research and monitoring programmes. In 1969 FAO, UNESCO, and WMO organised a series of meetings with the aim of enhancing the utilisation of the oceans and their resources for the benefit of man, and in 1970 FAO organised a major technical conference on marine pollution and its effects on living resources and fishing. In 1974 UNEP initiated the Regional Seas Programme with the objects of:

(a) promotion of control of marine pollution and management of aquatic resources
(b) assessment of marine pollution
(c) coordination of efforts in the management of marine and coastal resources
(d) support of education and training in developing countries for the protection, development, and management of marine and coastal resources.

There are now 10 regional seas programmes in operation involving over 120 countries, with an 11th programme under active investigation for initiation. These cover most of the coastal waters around the globe except where there are other mechanisms for regional cooperation such as in the Baltic and North Seas. (Figure 1).

Appendix I indicates the extent of participation by Commonwealth countries in the Regional Seas Programmes. Of the 59 Members and Associated States of the Commonwealth who have maritime frontiers, 43 are participants in operating programmes or are taking active part in negotiations towards the initiation of a new programme. The details of the action plans of the regional seas programmes are decided by a consensus of participants. Hence, because of this extensive involvement, the programmes developed and the actions taken under the regional seas programmes are indicative of what Commonwealth countries are seeking from cooperative studies to guide them in the management of their coastal zones.

Reports prepared for two of these regional programmes have been drawn on extensively in preparing this paper. They are:

The State of the Environment in the South Pacific - A L Dahl and I L Baumgart. UNEP Regional Seas Reports and Studies No 31. 1983.

Note by the Director of the South Asia Cooperative Environment Programme on Regional and National Activities Relevant to the Development of an Action Plan for the Protection and Management of the South Asian Seas Region. UNEP March 1984.

3. Fields of interest in coastal zone management

3.1 The land/ocean interface

3.1.1 Characterization of the coastal zone

As a first step towards considered management of their coastal zones some countries have undertaken coastal zone surveys, generally consisting of simple "walk-along" documentation of what is there and what processes are taking place, including consultation with residents and workers, such as fishermen, in the zone. The results are recorded as a map of coastal zone resources. New Zealand, India, and Sri Lanka are well advanced in this field.

Eventually such surveys might be upgraded to become inventories of coastal ecosystems.

3.1.2 Land stability

In all countries, from small islands to continental land masses, there is uncertainty about the dynamics of the land/ocean boundary, and the effects of man's activities on natural processes of erosion, sedimentation, and along-shore movement of sediments. Dealing with effects of high storm conditions, tsunamis, trends of change in sea levels, and excessive supplies of sediment induced by land based activities such as deforestation and mining, requires a good understanding of sedimentation processes and considerable skills in coastal engineering.

3.1.3 Development of newly emerged land

On actively prograding foreshores such as deltas there are considerable areas of newly emerged land with particular chemical and physical soil characteristics requiring special treatment to ensure maximum sustainable production without decreasing the productivity of adjacent coastal waters.

3.1.4 Recreational uses

The rapid expansion of tourism is impinging heavily on coastal zones throughout the world. High concentrations of people in tourist hotels, welcomed for their contribution to the local economy, but discharging large quantities of solid and domestic waste, drawing heavily on local fresh water, demanding modifications to the sea margin specifically to raise its recreational qualities, are applying pressures quite different from established local practice and radically affecting the natural stability of the coastal ecosystems. Tourism in appropriate situations can be a highly productive use of the coastline, but there have been examples of tourism destroying the very environment which attracted the tourists. Controlling authorities are seeking information on which to base judgments on the optimum balance to be achieved among tourism, production, and conservation in the coastal zone.

3.2 Marine production

3.2.1 Fishery management

A large proportion of the fish requirements of developing countries is taken form the reefs, lagoons, estuaries and shallow sea waters of the coastal zone. Protection of these waters from deleterious land-based discharges, from excessive sedimentation and from over-exploitation is a basic requirement for maintaining inshore fisheries. In some areas excessive taking of reef fish as bait for deep sea fishing has caused considerable concern.

There is a big range of fish habitats in coastal waters - examples are the extensive shallow waters at the head of the Bay of Bengal caused by sediments form the Ganges River, the narrow continental shelf around Sri Lanka, and the extensive coral atoll systems in deep water oceans such as Kiribati and the Maldives. Each system requires its own studies, but fishery management principles developed in one situation can have applications in similar habitats elsewhere. Most countries are seeking to the best of their abilities to manage their coastal waters to produce maximum sustainable production of fish and shellfish, but many are seeking external advice and regional research projects. Countries with high populations in relation to their land area such as Bangladesh and the Maldives see their coastal waters as their only new resource with the potential to significantly increase the production of food for their people.

3.2.2 Aquaculture and mariculture

"Fish farming" has been highly effective in some developing countries, and has the potential for considerable further development in many other regions. Strength in planning authorities and sound technical knowledge is necessary to set aside coastal waters with conditions suitable for fish culture. There is scope for sharing of expertise and experience.

3.3 Land-based pollution

3.3.1 Excessive sedimentation

It has been estimated that only 10% of all material entering coastal waters from rivers or from land run-off eventually reaches the open sea. Changes of land use or vegetative cover, (especially deforestation in upper river catchments), mining and earth moving, have in many areas increased sedimentation at the coast, destroying stable biological systems in the shallow waters, estuaries, and lagoons, and weakening the growth of coral reefs. Some of these effects may upset the basis of marine food chains which extend into the oceans far beyond the actual area of sedimentation.

In this way management of the land far inland may be of great importance to the coastal zone, leading to real difficulties of definition of "the coastal zone", and to assigning responsibili for coastal zone management.

3.3.2 Industrial effluents and discharges

In many areas of concentrated industrial activity toxic substances such as heavy metals used in industrial processes are discharged directly or indirectly into coastal waters, sometimes to be concentrated in the marine biological food chain and to return to land as a toxic contaminant of fish for human consumption. Excessive discharges of organic materials may deplete oxygen in the receiving waters, so that their productivity is reduced. More diffuse pollution from agricultural production, including leaching of fertilisers and spillage of pesticides, and from dispersed processing industries such as tanneries, induce widespread general lowering of the quality of coastal waters. Heat from cooling systems of power stations, spillages of oil during loading and unloading of tankers, from storage, and at points of use,are further sources of land-based pollution. Methods of control are generally known, but the means of enforcement have not been achieved in many countries

3.3.3 Domestic effluents

In most developing countries urban development caused by people moving from rural areas to government and commercial centres is a major trend. In heavily populated countries huge cities are expanding rapidly, but even in small countries the aggregation process is going on,bringing problems of urbanisation. Wherever there are such concentrations of people the disposal of sewage, domestic wastes, and the solid wastes of disposable products (such as beer bottles, food cans, and car bodies) will be a determinant in the quality of coastal waters. Sanitary engineering of disposal systems suited to the sizes of communities and to the range of environments will be a continuing requirement of developing countries.

3.4 Sea based pollution

3.4.1 Pollution from ships

Developing countries, especially those heavily dependent on their coastal waters for their subsistance and who are close to main oil tanker routes, have deep concern about the potential effects of major oil spills from tanker accidents. Many find themselves at risk from super tankers passing close to them, but heading for destinations in the developed countries. The International Maritime Organisation has been very effective in developing schemes for regional cooperation in combatting oil spills from shipping accidents, in establishing construction standards for international shipping, and in developing codes of practice among shipowners on oil discharges and tank washing, dumping and release of debris at sea. But many countries are still seeking assistance in developing their own contingency planning against oil spills so that they can key into regional contingency plans as they are developed.

3.4.2 Pollution from offshore mining, oil prospecting and production

With the ever extending searches for seabed minerals and for offshore hydrocarbons, the potential is increasing for serious pollution of adjacent coastal waters. In two areas regional Committees Coordinating Offshore Prospecting (CCOP in South East Asia and CCOP-SOPAC in the South Pacific) are operating. A further committee (CCOP-IO) is in process of being set up for the Indian Ocean. Such bodies can be reasonably charged

by their members to ensure that pollution from their operations is controlled to specific standards. But many developing countries are concerned that they have insufficient expertise to ensure that environmental standards are specified and monitored for prospecting and production operations affecting their coastal waters by commercial prospecting companies.

3.5 Energy

Decreasing supplies of readily accessible indigenous firewood, and the high price of fossil fuels are forcing developing countries to give attention to other forms of energy. Hydroelectric and geothermal sources are available in some of the larger countries, but at very high capital cost. Various forms of solar energy have some applications in developing countries, but also are limited by cost.

The most practicable short term development would seem to be the replacement of indigenous firewood by wood from exotic tree plantations, together with the local production of more efficient wood-burning cookers designed for local needs, and making use of local materials.

High diesel fuel costs are reducing the radius of fishing in some countries, putting greater pressure on fisheries in coastal waters. The diversion of coconut oil products from copra into a liquid fuel which could be used in the simple diesel motors of powered fishing boats could extend the fishing zone again, and thus benefit the closer coastal waters.

4. Resources of the coastal zone

4.1 Mineral resources

4.1.1 Sand and gravel from the shore

Removal of sand and gravel from coastlines leads to beach loss and coastal erosion. Large islands and continental countries have alternative land-based sources of aggregate for building construction and paving which can be used while conserving the coastal sources. But in small coral islands there is often no other source than coral rock from the reef or coral sand from beaches or lagoon floor for lime burning and for building construction. As well as inducing coastal instability, dredging of the lagoon bottom destroys biological habitat, causes pollution of the coastal waters, and reduces productive fisheries resources. Removal of coral from the reef may reduce the protection of the islands from stormy seas, and will further damage fish habitat.

Mining of coral on the small islands therefore entails securing essential construction materials without destroying the very land on which the construction will be placed. Successful management of the resource requires a sound scientific base of sedimentology, coastal engineering of a high standard, and firm administration by controlling authorities.

4.1.2 Water

Water, in many small island countries and in the dry zones of larger countries, is the most limiting natural resource. In many of the larger countries the problems of freshwater supplies in the coastal zone have become worse through poor water management inland, leading to pollution and sediment-loading of rivers and lakes. Excessive withdrawal from the freshwater tables by wells in the coastal plains has in some countries resulted in lowering of the water tables and incursion of seawater into previously freshwater bodies. Even in zones of adequate rainfall the management of the freshwater/saltwater interface in both surface waters and ground waters is presenting problems in many developing countries as freshwater demands and polluted water discharges increase.

In the smaller island countries dependent on interception of rainwater and on freshwater lenses between the saltwater table and the land surface, the state of the freshwater lens and the dynamics of its depletion and recharging are critical to the life of the people. But little information is available. A substantial contribution could be made to ensuring the sustainability of community life in these islands by applying known geophysical techniques to the quantitative characterisation of the ground water resource. Based on this information sound procedures could be worked out for the efficient utilization and conservation management of the available water resource, avoiding crisis situations in which emergency freshwater has had to be carried by air over long distances to islands whose reservoirs have been exhausted.

4.1.3 Mangroves

Mangrove forests have been documented as areas of high productivity of great importance to coastal fisheries. They are important in controlling coastal erosion, especially in protecting coastal areas against storm damage. They are sensitive to changes in water salinity and pollution by oil and certain industrial pollutants, but can be useful in the treatment of urban wastes if carefully managed. They are important for subsistance fishing, as a habitat for organisms at the early stages of the marine food chain, and as a source of timber and firewood for communities in the coastal zone.

The largest mangrove forest in the world is at the mouth of the Ganges River, and the Bangladesh Department of Forests has a substantial scientific programme to enhance the rich biological habitat of the mangrove ecosystem, and to manage mangrove forests as a productive resource on a sustainable yield basis. Regional seminars in South Asia and the Pacific have strongly supported this programme.

5. Special ecosystems within the coastal zone

5.1 Coral

Coastal zone management in most developing Commonwealth countries involves coral. Coral provides protection for the land from the sea; it is an important biological unit in marine life; it is a valuable but limited resource for limestone and for decorative purposes; it provides a base for recreation and tourism; it is the sole constituent of many islands on which people live.

The coral reef ecosystem is highly productive, fragile, and easily disturbed when pushed beyond its limits. Extensive degradation of reef and lagoon resources is reported from the Pacific, the Indian Ocean and the Caribbean, attributed to dynamiting for fish, mining for decorative corals, siltation and smothering, and construction activities. The "Crown of Thorns" starfish, though probably a natural phenomenon, has done considerable damage from which recovery may be slowed down by human disturbances.

When so many communities surrounded by deep open ocean are completely dependent on coral for their small land base, for their soils, for their food supplies, and for the protection and continuation of their habitat, a sound scientific base on which managament decisions and engineering projects can be built would seem essential. There are several centres of coral research, but there appears to be a need for more field work on surveys of distribution and condition of ecosystems, so that strengths and weaknesses of the system can be determined, and uses and abuses quantified.

5.2 Small island ecosystems

Small islands, though containing only a minor proportion of the people of the Commonwealth, are especially dependent on sound knowledge and careful management of the coastal zone. There is no hinterland from which to draw water or other resources, and no alternative human habitat to which to withdraw should the present habitat become untenable. The biological system is delicate and unbuffered.

Traditional techniques, customs, and standards of behaviour have evolved to ensure that communities can maintain themselves within the limits of the ecosystem. But, with the adoption of imported social objectives and standards, many of the traditional guidelines are being lost, and the whole system is having to adjust to accommodate to the change.

Agricultural development is an example of this: the adaptation of efficient modern commercial methods of agricultural production to the micro environment of small maritime units involves much more than scaling down in size. There are real practical difficulties in isolating pesticides and herbicides from food during transport, storage, and use in a micro environment which do not occur in larger countries. In the coastal zones, because food is continuously harvested from contiguous land and sea environments, it is especially necessary that practices used to increase land production should not be deleterious to immediately adjacent water production areas. This is an important consideration in designing fertiliser regimes.

There is great scope for sympathetic and constructive socio-economic studies to identify means of protecting such vulnerable ecosystems while seeking to incorporate traditional customs and standards into sound economic development activities suited to the particular cultures and environments and conserving the natural heritage of the islands and their peoples.

6. A role for the Commonwealth Science Council

The new programme of the Commonwealth Science Council includes an expansion of project activities to encompass optimum utilization of the potential of the coastal resources of developing countries.

The foregoing overview has illustrated the great scope there is to improve management of the coastal zone, and has indicated some of the gaps in scientific information which must be filled if management is to proceed on a sound basis.

The fact that there are extensive regional programmes in operation in the coastal zones throughout the world reflects the desire of countries to improve coastal zone management, and their willingness to work together on the problems involved by pooling information and expertise and by working collaboratively. It does not indicate that adequate resources are available or that international funding is readily accessible. The United Nations system has provided seed capital for initiating these programmes, but, once established, they depend on contributions in cash and kind from participating countries and on funds for individual projects sought from all relevant sources.

Many of the developing countries are finding great difficulty in making their contribution to the programmes because of their shortage of external funds and their limited technical resources of manpower and equipment. But their participation in the planning of regional programmes has made them aware of what needs doing in their own countries to improve their own management and to contribute to regional improvements. It has also encouraged a longer perspective and a continuity of programme for the improvement of the coastal zones.

To assist the developing country to make its contribution in kind to the regional programme CSC might consider providing a suitable expert to organise a project within the programme.

The regional approach being adopted so widely means that each developing country can concentrate its attention on a limited number of aspects of coastal management and draw information on other aspects from other participants in the programme. But some countries need assistance in achieving even these limited objectives.

CSC might assist with the training of personnel for investigation and monitoring duties within a regional programme and with the provision of equipment meeting the performance and reliability standards of the regional programme.

Though there is a scarcity of scientific manpower in many developing countries, the limiting factor is probably employment opportunities rather than graduate training opportunities. The List of Scientific and Technological Capabilities of Commonwealth Countries indicates the substantial university systems available - many setting high standards of academic performance. The recent substantial increases in cost of university training in developed countries have encouraged students to attend universities within their own regions for both undergraduate and postgraduate studies, with benefits for those universities and a strengthening of regional identity.

The development of management programmes from individual scientific research projects requires the capacity to integrate a range of scientific disciplines into administrative and legal procedures and cultural situations. Multi-objective planning is a difficult concept to incorporate into administrative operations in any country, but many of the developing countries completely lack this type of expertise.

CSC might make a major contribution by facilitating post-graduate training in integrative methods and multi objective planning.

There are centres of expertise in Commonwealth countries whose skills could be put to wider use throughout the Commonwealth. Examples are the Indian National Institute of Oceanography at Goa which has an outstanding international reputation, including coastal waters, and the Coast Conservation Department of Sri Lanka which has a well advanced Coastal Conservation Management Plan, and a comprehensive coastal engineering research programme.

CSC might facilitate exchange of personnel, the organisation of workshops, and the dissemination of information in centres of excellence such as these.

In the main, progress in coastal zone management is not dependent on new technology, but rather on the application and adaptation of established technology to the circumstances of developing countries, and integration of the results into their government administration.

CSC might assist this process by facilitating the matching of appropriate research institutions between developed and developing countries, and between developing countries, so that technical resources can be drawn on and expertise readily transferred. (Long term bilateral arrangements have been particularly productive.)

Some of the initiating stages of coastal zone management schemes, such as the characterisation of the zone by walkalong survey, can have real value in creating public interest and understanding of objectives by informal consultation with people living in the zone. A high level of scientific expertise may not be required, but experience and considerable organisational ability is necessary to define the parameters within which the project will be undertaken, the data which should be collected, how local people should be consulted, how the information should be recorded, and the ultimate form of its publication, so that

it may have the greatest use in coastal zone management.

CSC might assist countries wishing to undertake characterisation surveys of the coastal zone by providing experienced advisers to assist local survey teams.

Legislation covering management of the coastal zone varies greatly among developing countries from simple customary controls to sophisticated and stringent legal instruments. Many countries are creating more effective legal bases for the management of their resources, including coastal resources. However many of the smaller countries have expressed their need for assistance in responding to international agreements for the protection of the marine environment - in particular the relationship of such agreements to the management of their coastal zones, and the advantages and disadvantages of becoming parties to international conventions.

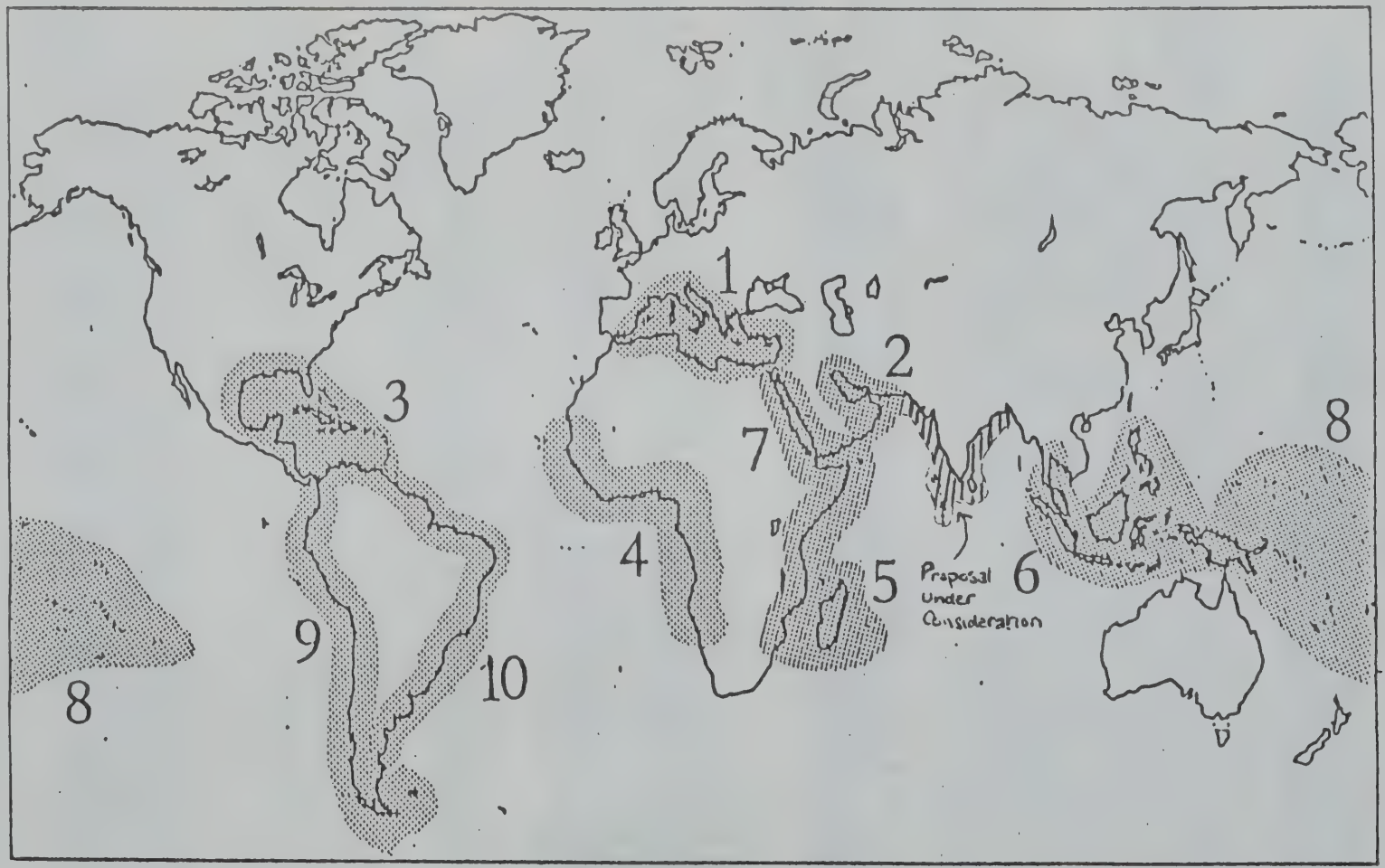
CSC might be able to arrange practical advice and assistance to small Commonwealth countries on the scientific/legal aspects of international agreements on protection of the marine environment.

The Commonwealth Science Council's Expanded Programme for Scientific Cooperation describes three stages of development:

(a) Direct satisfaction of basic physiological needs
(b) Improvements in quality of life through economic benefits
(c) Improvement in recreation and leisure

The development of coastal zone management contributes to all three stages in the great majority of Commonwealth countries.

Figure I : Geographic coverage of UNEP Regional Seas Programme



1.	Mediterranean Region	(Action Plan adopted: 1975; Regional Convention signed: 1976)
2.	Kuwait Action Plan Region	(Action Plan adopted: 1978; Regional Convention signed: 1978)
3.	Caribbean Region	(Action Plan adopted: 1981; Regional Convention: in preparation)
4.	West and Central African Region	(Action Plan adopted: 1981; Regional Convention signed: 1981)
5.	East African Region	(Action Plan preparation initiated)
6.	East Asian Region	(Action Plan adopted: 1981)
7.	Red Sea and Gulf of Aden Region	(Action Plan adopted: 1982; Regional Convention signed: 1982)
8.	South-West Pacific Region	(Action Plan prepared for adoption in 1982)
9.	South-East Pacific Region	(Action Plan adopted: 1981; Regional Convention adopted; 1981)
10.	South-West Atlantic Region	(Action Plan preparation initiated)

Appendix I

Participation by Commonwealth Countries in UNEP Regional Seas Programmes

1. Mediterranean Region
   - Cyprus
   - Malta

2. Kuwait Region
   - --

3. Caribbean Region
   - Bahamas
   - Barbados
   - Belize
   - Dominica
   - Grenada
   - Guyana
   - Jamaica
   - St Lucia
   - St Vincent & Grenadines
   - Trinidad & Tobago
   - United Kingdom

4. West & Central African Region
   - The Gambia
   - Ghana
   - Nigeria
   - Sierra Leone

5. East African Region
   - Kenya
   - Mauritius
   - Seychelles
   - Tanzania

6. East Asian Region
   - Malaysia
   - Singapore

7. Red Sea/Gulf of Aden Region
   - --

8. South Pacific Region
   - Australia
   - Cook Islands
   - Fiji
   - Kiribati
   - Nauru
   - New Zealand
   - Niue
   - Norfolk
   - Papua/New Guinea
   - Pitcairn
   - Solomon Islands
   - Tokelau
   - Tonga
   - Tuvalu
   - Vanuatu
   - Western Samoa

9. South East Pacific Region
   - --

10. South West Atlantic Region
    - --

11. South Asia Region
    (still under negotiation)
    - Bangladesh
    - India
    - Maldives
    - Sri Lanka

NON-LIVING MARINE RESOURCES OF THE ASIA PACIFIC REGION

D S Cronan
MARINE MINERAL RESOURCES PROGRAMME, IMPERIAL COLLEGE

The area considered in this report includes the Indian Ocean east of the Carlsberg Ridge at about 60°E, the Bay of Bengal, the waters around Thailand, Indonesia and Malaysia, and the South Pacific Ocean west of the longitude of the Line Islands (Kiribati), approximately 160°W. This large area contains all the CHOGRM member countries, Australia, Bangladesh, Fiji, India, Kiribati, Malaysia, Maldives, Nauru, New Zealand, Papua New Guinea, Singapore, Solomon Islands, Sri Lanka, Tonga, Vanuatu and Western Samoa, as well as a number of other countries.

Mineral Deposits

Six types of mineral deposits of potential economic value occur on the sea floor. These are aggregates, placers, precious coral, phosphorites, metalliferous muds including polymetallic sulphides and manganese nodules and cobalt rich manganese encrustations. All have the potential to occur within the area defined above, but occupy different parts of it.

Aggregates

Marine aggregates are primarily used as construction materials, in concrete making, as road metals, etc., and comprise largely quartzose sands and gravels, and corraline and shell sands. They occur both on beaches and in the offshore area. Because aggregates are a low cost commodity, transport charges are a major factor in their usage. Thus, to be of value, marine aggregates must preferably occur near the site of usage (most marine aggregate used in the London region, for example, is dredged from the southern North Sea and the eastern English Channel), and have to be used in the coastal region. Long distance inland transport becomes prohibitively expensive.

In the region of the present study, marine aggregates are achieving an increasing usage, especially in the small island nations. Large countries such as Australia, New Zealand and India can supply most, if not all, of their aggregate requirements from onshore sources, but this is not the case with the small island nations of the Pacific such as Tonga, Vanuatu and Western Samoa, etc. Because of their small land areas, such countries do not have readily available on land aggregate to satisfy future construction requirements. This problem is compounded by the fact that some of the small island countries, especially in the Pacific, are undergoing rapid tourist development necessitating the construction of new hotels, airports, etc. while at the same time needing to preserve their beaches (often the main source of available aggregate) as a tourist facility. In such situations, offshore aggregate is often almost the only source of building material.

Currently in the South Pacific, several island nations are exploiting offshore aggregate, or have plans to do so in the near future. Surveys off the Cook Islands have shown the presence of aggregates in the Avarua

Channel. The sand fraction of this material is worn coral and the gravel fraction consists of basalt pebbles. In Western Samoa, Solosolo Beach on the north coast of Upolu Island has been surveyed for construction materials, but the removal of beach material was not recommended on environmental grounds. On Tongatapu, sand is being mined from beaches on the southeast and west coasts, but this has caused some beach erosion and environmental damage. Offshore surveys to find alternative aggregate deposits to those on beaches have been carried out, and a promising find is located in water depths between 6 - 30 m to the south of Fafa and Velitoa islands, about 6 km to the north of Nuku' Alofa, consisting of about 4 million cubic metres of fine to medium shelly carbonate sand.

The mining of calcium carbonate for cement manufacture is also of importance in the area of the present study. The large nations such as Australia, New Zealand and India have abundant supplies on land, and thus will not need to look offshore. This is not the case with the smaller island nations. In Fiji, for example, $CaCO_3$ is mined in Laucala Bay, principally for use in cement manufacture, but also for lime production. Similar operations off other islands will probably be needed as onshore supplies become progressively depleted.

Placers

Marine placers are detrital heavy metallic minerals which have become separated from their normally associated light minerals, to form potentially economic concentrations. The most important examples in the present region are cassiterite (tin), ilmenite (titanium), rutile (titanium), zircon (zirconium), chromite (chromium), monazite (thorium), magnetite (iron), and gold. Marine placer minerals tend to be localised in extent, occur in relatively near shore situations and closely reflect the composition of the rocks of the hinterland.

Within the area dealt with in this report, the main placer mining activity is cassiterite mining off Indonesia, Thailand and Malaysia, which has been continuing since the early years of this century, and represents one of the World's major placer mining operations. Placer minerals also occur off India and Sri Lanka where there are exposed high energy coastlines. Rutile and zircon have been produced from the beaches of Sri Lanka, and monazite and ilmenite from off Kerala in South India. Recent re-interest in offshore placer minerals in India and Sri Lanka has prompted renewed exploration efforts. In India both the Geological Survey and the National Institute of Oceanography are involved, the latter having recently located some promising deposits off the Indian west coast. In Sri Lanka, assessment of some of the beach deposits has been extended seawards in collaboration with a West German mining concern.

In the South Pacific, several nations have either mined placers, or are expressing interest in them. Rutile, zircon and monazite have been produced from beaches in East Australia, and a recent evaluation of some offshore placer prospects has been carried out in collaboration with West German mining interests using the German vessel Sonne. Iron sands have been known off the west coast of North Island, New Zealand, for over a century, and sporadic attempts have been made to exploit them. Their main constituents are iron and titanium oxides. New Zealand beaches also contain deposits of iron and titanium bearing minerals. Placer

mineral exploration has also been taking place off some of the small island nations of the South Pacific. Gold has been sought in offshore sediments transported from the Gold Ridge area of Guadalcanal, Solomon Islands, but with disappointing results. In P.N.G., significant deposits of titanium bearing magnetite are found in beach sands, particularly on S.E. Papuan beaches, and there is interest by CRA Exploration Pty (Melbourne) in alluvial chromite located in bays on the Marobe Coast south of Lae. Four and one half million tons of chromite have been reported. In Vanuatu, iron rich beach sands occur in the vicinity of Port Patteson, and contain up to about 15% iron. Values of up to 14% iron occur in sediments offshore. In Fiji, magnetite bearing sands occur on beaches and offshore from Singatoka. Reserves of 1.8 million tons of magnetite minerals has been established in the deposit near Singatoka. Small placer deposits have been found near a number of other islands. However, as an extensive hinterland is normally required for placer mineral occurrence, many of the island nations of the South Pacific would not be expected to have placers offshore because of insufficient land areas. Furthermore, coral reef development dissipates wave energy needed to concentrate placer minerals, thus further reducing the likelihood of their occurring extensively off the smaller Pacific nations.

Precious Coral

Although living, precious corals, because of their usage, are best classified with non-living resources. They are used in the jewellery industry and until the beginning of the 19th Century were known only in the Mediterranean. However, today precious coral is recovered almost exclusively in the Pacific. Precious corals are much harder than normal corals, are found in deeper water, and can be polished into jewellery which is saleable as an adjunct to the tourist industry. Pink, red, gold or black are the colours of precious corals.

Black corals of commercial value are generally found between 25-100m depth on hard sea floor, grow as much as 6 cm/yr and can live for up to 100 years. They are widespread in the Pacific, and although no commercial beds have been found in the area considered in this report, encouraging sites have been found off the Solomon Islands, Vanuatu and Tonga.

Pink corals are most abundant in areas swept by relatively strong currents, and which are free of sediment. They occur in commercial quantities only in small beds.

Gold corals are apparently confined to off Hawaii and Alaska only.

No occurrences of precious coral are known to the writer from the eastern Indian Ocean, but depositional conditions are similar to those in the western Pacific, and thus they should occur there.

The manufacture of jewellery from precious coral is labour intensive, and as such should form a useful supplement to the tourist industry in areas of the S.W. Pacific and east Asia where such an industry occurs. An area of particular importance in this regard would be the S.W. Pacific where many of the small island nations are developing their tourist industries and at the same time have a potential for commercial precious coral occurrences. Further exploration around such islands as Tonga, Vanuatu, Fiji, Kiribati and the Solomon and Cook Islands would appear to be warranted.

Phosphates

Phosphates in the form of phosphorites are composed of calcium phosphate which is an important fertilizer, and thus are of principal use in agriculture. Offshore phosphorites tend to occur in waters of medium depth (middle and outer continental shelf), and on oceanic seamounts. Two areas of known present day phosphorite deposition are off Peru-Chile and Namibia, with possibly a third off the west coast of India, but a number of fossil occurrences are known in the present study area, some of which may have an economic potential.

The largest and potentially most exploitable phosphorite deposit known within the present study region is on the Chatham Rise off New Zealand. This deposit has been extensively surveyed by a combination of New Zealand and West German interests, and offers promise as a substitute for imported phosphate in New Zealand when traditional sources such as occur on Nauru, Ocean and Christmas Islands run out. An important property of Chatham Rise phosphorite is that it can be applied to soils directly, without processing, thus reducing the cost of its use.

No other large phosphorite deposits are known in the area considered in this report, with the possible exception of off the west coast of India. Recently the Indian National Institute of Oceanography have reported the finding of a sizeable low grade phosphorite deposit extending offshore from Cochin to Bombay, and consisting of a fossil coral reef which has been phosphatised and submerged. Phosphorus grades are low, only about 5%, but the size of the deposit, its closeness to shore, and India's need for fertilizer, might make it economic to mine in the future.

The other main situation in which phosphorites occur in the study region is on oceanic islands and on seamounts or in atolls. The large, commercially valuable deposits of Nauru, Ocean and Christmas Islands are well known, and there is the potential for similar deposits to occur on shallow submerged seamounts within the region which were above sealevel prior to the last sea level rise. Drilling in coral atoll lagoons for phosphorite has been taking place in French Polynesia for a number of years, with some encouraging results. Similar activities in the Cook Islands, Kiribati and the Andaman Islands and the Maldives and Tonga might also be warrented.

The main value of offshore phosphorite in the economics of the nations of the study region would be in the form of import substitution. At the moment, most of the countries in question import phosphate fertilizer, some from as far away as the U.S.A. Much of the needs of the region is being met by the three island deposits mentioned above (Ocean, Christmas and Nauru), but these will probably not last beyond the end of the century. Locally available deposits will then need to be found in order to avoid excessive transport costs. This will be especially so for many of the small island nations of the South Pacific whose agricultures are small and who probably could not support major phosphorite import.

Metalliferous Sediments and Polymetallic Sulphides

Metalliferous sediments are composed of mixtures of copper, zinc and iron sulphide minerals, and iron and manganese oxides, all of submarine volcanic origin. Only the Cu and Zn sulphides are of economic

interest. When unconsolidated, the deposits are called metalliferous sediments (muds) and when consolidated they are called polymetallic sulphides. They occur in two oceanic settings, on mid-ocean ridges and in island arcs, both of which are volcanically active. The best described deposits to date occur in the Red Sea. No mid-ocean ridges occur in the present study area, and thus it is only in the island arcs of the eastern Indian Ocean and the S.W. Pacific that such deposits could be expected, specifically in the island chains of Indonesia, the Solomons, Vanuatu and Tonga, together with some of the intervening basins, and in the Andaman Sea.

First reports of metalliferous sediments in Indonesian waters date from 1964, and in the Tonga region and off New Zealand from the early 1970's. Recent work in the S.W. Pacific has demonstrated several areas where such deposits might be expected (Cronan, 1983). These are on the Tonga-Kermadec Ridge between Tonga and the Kermadec Islands (N.Z.) and south towards New Zealand itself, in the Lau Basin between Tonga and Fiji, in the North Fiji Basin between Fiji and Vanuatu, along the Vanuatu Island chain, along the Solomon Island chain and in the Bismarck Sea between New Britain and New Ireland (P.N.G.).

It should be emphasised that no economic concentrations of metalliferous sediments or polymetallic sulphides have been found in the study region, but little effort has been devoted to looking for them. However, there are such deposits on land in the Solomon Islands which formed in a submarine setting and subsequently became uplifted. Similar deposits also occur on land in the Japanese island arc in the N.W. Pacific in a comparable geological environment. Thus the potential for occurence of sea floor metalliferous sediments and polymetallic sulphides in the S.W. Pacific is good, and greater effort should be devoted to searching for them.

Manganese Nodules and Cobalt rich Manganese Encrustations

Manganese nodules are potato sized concretions of iron and manganese oxides which can contain economically interesting concentrations of Ni, Cu and Co (up to about 3% combined), which occur on the deep sea floor. Cobalt rich manganese crusts are similar in their overall nature to manganese nodules, but occur as coatings or encrustations on hard rock substrates, on seamounts and the submerged portions of islands, and can be enriched up to 2.0% in Cobalt.

Manganese nodules of potential economic value are known to occur in three areas of the oceans, two within the present study region, and one outside. The one outside is in the N.E. equatorial Pacific and has been subjected to the greatest attention by international deep sea mining consortia. The two inside the present study area are of more recent discovery, one in the central Indian Ocean, and the other in the S.W. equatorial Pacific.

The best central Indian Ocean manganese nodules from the economic point of view occur at about 8-15°S between about 70°-90°E in a water depth of about 4500-5000m. They appear to be associated with a sub-equatorial divergence leading to increased phytoplankton activity in

the surface waters with concommitant supply of metal bearing organic remains to the sea floor. Preliminary work on these deposits was done by several groups, including that of the writer, but the major effort there now is by the Indian National Institute of Oceanography. This organisation is surveying the region as far south as 30°S in order to find a potential manganese nodule mine site.

The S.W. Pacific manganese nodule fields are more scattered than that in the central Indian Ocean, and parts appear to occur within the Exclusive Economic Zones of some of the island nations of the region. Data are scarce, and while grades (Ni + Cu + Co) appear to be good in some areas (noteably between the island groups that comprise Kiribati), abundances are variable. However, recent Japanese and CCOP/SOPAC work (see below) has demonstrated a coincidence of good grades (more than 2.5% Ni + Cu + Co) and good abundances in the sub-equatorial regions north and south of the Equator, parts of which occur within the Exclusive Economic Zone of Kiribati. Deposits occurring within E.E.Z.s would be under the jurisdiction of the adjacent island states and not under the propose United Nations International Seabed Authority.

Cobalt rich manganese crusts, as the name implies, are rich in Co (up to about 2.0%). They are known to occur in the Line Islands (Kiribati) at water depths of between 500-2000m and also have the potential to occur on seamounts in other equatorial and sub-equatorial parts of the study area.

Although the economics of manganese nodule and cobalt rich crust mining is not favourable at the present time, this will probably change before the end of the present century. With two of the three known potentially economic nodule deposits, and some of the known cobalt rich manganese crust occurrences within the study region, more research on these deposits would be useful.

Future Work necessary to develop the Non-Living Resources of the Study Region

While it will be evident from the previous sections that much is known about the mineral resources of the study region, much more needs to be learned before their full potential can be realised.

By the very nature of the mineral deposits concerned, placer and aggregate exploration and exploitation are geographically localised endeavours. However, technical assistance is needed in order to explore poorly known parts of the region for the purpose of defining exploration targets, plan surveys, and ultimately recover any deposits found. This applies particularly to the Pacific island nations. Aggregate will be of more immediate importance than placers in their immediate future development, but offshore placer mineral exploration should continue, particularly around the larger islands such as Sri Lanka, and P.N.G., and off Malaysia. One spin off from such exploration is that anomalous concentration of metals in the offshore area, while if they themselves are not of economic interest, can point to mineralisation on land in the adjacent coastal area,

and thus provide a focus for exploration there. Geochemical exploration techniques are well suited to this sort of work.

Precious coral is already beginning to be sought within the study region, and this trend should continue, especially in the vicinity of the Pacific island nations mentioned in the previous section. However, a more systematic approach to exploration should be considered, other than simply using tangle nets which has been the case up to now. Furthermore, when recovery takes place, it should be on a conservation minded basis. Much unnecessary precious coral depletion has taken place in the N.E. Pacific where recovery has been going on for some time, as a result of inefficient recovery techniques.

Phosphorite exploration within the study area is in its infancy, and much more work needs to be done. The efforts of the Indian and New Zealand Oceanographic Institutes in this regard are to be commended, but have only addressed the problem at opposite ends of the region. Probably, the most promising sites for future phosphorite exploration are on shallow submerged seamounts and coral atolls within the equatorial and sub-equatorial South Pacific, and possibly in the eastern Indian Ocean. As mentioned, atoll drilling in French Polynesia has shown encouraging results in regard to phosphorite exploration, and similar efforts, together with conventional dredging of seamounts, should be carried out. Chemical analysis of previously recovered marine sediments for P on a regional basis, could help to define areas of phosphorite occurrence.

Metalliferous sediments and polymetallic sulphides have been the least sought of any of the mineral deposits in the region, partly because they are of very recent discovery. However, a technical report prepared by the writer for CCOP/SOPAC (Cronan, 1983) has indicated several areas of possible occurrence associated with some of the island groups and their intervening basins in the S.W. Pacific. Some of these areas are currently targets in the ANZUS programme (see below), but additional work needs to be done, especially in the Lau Basin between Tonga and Fiji where several promising indications have been recorded.

There has been continuing interest in manganese nodules within the region for some years, and more recently in Co rich crusts, but apart from the Indian endeavours in the central Indian Ocean, little systematic effort has been put into this field of work. In view of the extent of the Indian endeavours, there is probably little point in additional surveys being done in the central Indian Ocean, but attention should be paid in that area to the scientific research aspects of the work in order that it can be of value in designing exploration programmes that can be applied elsewhere in the region.

The situation in the S.W. Pacific is quite different. There, manganese nodule research has been very piecemeal, and much of it carried out by groups from outside of the region, such as the Japanese and Russians. However, the possibility of potentially economic nodules (and cobalt rich crusts) occurring within the E.E.Z.s of some of the island groups (particularly Kiribati and Northern Cook Islands) has been highlighted in a report prepared by the writer for CCOP/SOPAC (Cronan, 1984), and necessitates a thorough exploration and evaluation of these areas for the deposits. Because the small Pacific island nations do not themselves have the capacity to carry out this work, it would best be arranged under aid agreements, utilising outside facilities and expertise (see below).

Current Workers and Programmes on Non-Living Resources within the Study Region

1. Research

Research to date on non-living marine resources within the study region has been carried out by a variety of groups and organisations. For example, in India it is the responsibility of the National Institute of Oceanography and the Geological Survey of India, in Australia of the Bureau of Mineral Resources, in New Zealand of the New Zealand Oceanographic Institute, and in Fiji of the Mineral Resources Department. In most of the remaining nations of the area, activity has been small and often no one organisation is responsible for it, if any.

Co-operative arrangements in the study of non-living marine resources within the region have been largely undertaken by U.N. organisations. The COOP groups and their UNDP projects have been particularly active in this regard. In the South Pacific, CCOP/SOPAC is almost entirely composed of Commonwealth countries, e.g. Fiji, Kiribati, New Zealand, P.N.G., Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa, and has played a major role in spearheading offshore mineral exploration within the region. In the far western Pacific and eastern Indian Ocean, a comparable and longer established group, CCOP/East Asia, has been active in offshore prospecting, but contains relatively few Commonwealth members. Finally, plans have been underway for some time to establish a CCOP/East Indian Ocean grouping to include India, Bangladesh, Sri Lanka and the Maldives, but as yet this has not been set up, and little inter-government co-operation in research and development on non-living marine resources is taking place in the Indian Ocean.

In addition to the work being carried out by groups within the region, work on non-living marine resources is also being done (and prepared) by nations or groups of nations from outside the area. An early example of this was the International Indian Ocean Expedition of the 1960's which provided much valuable baseline data in the eastern Indian Ocean. Recently, the Soviet Union has proposed a similar expedition in the S.W. Pacific, in which it would be a major participant. At present, this proposal is under evaluation. Probably the most active international programme in the region at the present time is the ANZUS (Australia, New Zealand and U.S.A.) programme in the S.W. Pacific to supplement the work of the UNDP project on exploration for mineral resources in the South Pacific, carried out under the auspices of CCOP/SOPAC. One group of cruises has already been carried out, and two more are planned, one for 1984 and one for 1985. Early results of this work are encouraging, and augur well for further endeavours in this programme.

Some assistance in non-living marine resource studies is given to the Commonwealth nations of the region by the U.K. in the form of bilateral aid posts. However, very few of these posts are totally dedicated to marine work.

2. Training

Training in the field of non-living marine resources in the study area is given in a number of different ways. Probably the most developed training programmes within the region are those carried out either by or

in collaboration with CCOP/SOPAC. These include training of CCOP/SOPAC member country staff at the CCOP/SOPAC - UNDP Project headquarters in Suva, Fiji, the organisation of training workshops at various places in the South Pacific region, and the import of experts to run training programmes. However, much of this training is at a fairly basic level, and advanced training in non-living marine resource studies has to be obtained outside the region. The situation in the eastern Indian Ocean is worse. Training of persons recruited for the newly initiated Indian work on non-living marine resources has had to be carried out on an in-house basis by the organisations themselves. There is an almost total lack of involvement in the subject within Indian Universities. The situation in Bangladesh, Sri Lanka and the Maldives is, if anything, worse still, with few, if any, training facilities in non-living marine resource studies available at all. This situation will need to be remedied on a priority basis if progress in the evaluation of non-living marine resources in the region is to be made.

Prospects for Technical Assistance and Scientific Co-operation in Research, Training and Information Dissemination

1. Research

The distribution of research effort into non-living marine resource in the study area is patchy. Some areas, such as the S.W. Pacific, for example, are well served by organisations such as CCOP/SOPAC and its ANZUS programme, and coastal India and the central Indian Ocean by the Indian marine minerals programme. In such areas, efforts by Commonwealth governments could best supplement those of existing organisations, rather than working in parallel. In other areas, such as west from P.N.G. to the central Indian Ocean, the effort is less focussed, and here Commonwealth countries such as Sri Lanka, Malaysia, Singapore and the Maldives might make useful individual or joint contributions.

The nature of Commonwealth assistance to research in the area would, in the first instance, best be in the form of Technical Consultancies in the field of marine mineral resource exploration and evaluation, attached to or working in relation to ongoing programmes in the region. In this way, the effects of shortfalls in several projects due to U.N. or national government spending cuts could be alleviated. Such a form of involvement would enable relevant agencies in Commonwealth countries of the region to gain direct experience, through consultant reports, in the non-living marine resource problems of the area, prior to the possible initiation of their own programmes. Within the region, such consultants could be drawn from Australia, New Zealand and India and outside of the region from the United Kingdom. Priority subjects for technical assistance in research through consultancies would be in exploration for and evaluation of mineral prospects within the Exclusive Economic Zones of the Commonwealth nations of the region.

2. Training

As indicated in a previous section, training in the field of non-living marine resources in the region in question, is very variable. This could best be remedied by (i) the provision of short concentrated

training courses within the region, and (ii) the sending of the brightest trainees to Commonwealth University departments dealing with the subject of non-living marine resources, in order for them to undertake higher degree research.

i) Training Courses - training courses of from one to several weeks duration should be an essential element in providing manpower familiar with non-living resource problems within the region in question. At present there are three courses which either have provided, or could provide, training of such a nature.

a) An elementary to intermediate course in marine geology organised by Victoria University of Wellington, which contain a non-living marine resource component (intermittent over three years).

b) Elementary workshops and bathymetric training courses organised by CCOP/SOPAC (one to several weeks in duration).

c) A short course (one week) on Marine Mineral Resources, organised by the Department of Geology, Imperial College, London, hitherto given only in London, but easily transferable to other locations.

These three types of course, supplemented and expanded, could probably provide most, if not all, of the basic training needs of the region in the field of non-living marine resources.

ii) Overseas Training - short training courses can provide a preliminary understanding of the subject in hand, but generally do not lead to a professional competance to practise it. Such is only obtained after long exposure to the subject under actual working conditions. This sort of training is best given in the Universities, through their higher degree system, and this facility should be provided to selected Commonwealth personnel either financed directly by individual Commonwealth governments, or through the various scholarship schemes available. Periods of study of from two to three years should be envisaged, at University departments in Commonwealth countries. In Australia, the Earth Sciences Dept. of the Australian National University has been involved with the subject of non-living marine resources, in New Zealand the Victoria University of Wellington, and in the United Kingdom the Department of Geology of the Imperial College of Science and Technology, London.

iii) Information Dissemination. The literature on the subject of non-living marine resources is very large and highly disseminated. There are few key journals or publications dealing with it. Most information on the subject is scattered through a wide variety of journals and this limits the number of centres (for expense reasons) where such information can be housed. At present, two main centres of literature on the subject within the region are at the N.I.O. India, and in the Mineral Resources Division and CCOP/SOPAC libraries, Suva, Fiji. These should be strengthened and a third set up, possibly in Malaysia or Singapore. Each centre should be encouraged to circulate lists of recent acquisitions to relevant agencies in Commonwealth countries, and provide periodic news sheets on the subject.

Location of Expertise

Expertise in the field of non-living marine resources is limited within the study region. Only Australia, New Zealand and India have significant numbers of personnel working on it. Elsewhere in the Commonwealth, the main source of expertise in the field is in the United Kingdom.

i) Technical Consultants. In Australia, the Bureau of Mineral Resources has been working in the field of non-living marine resources and has a limited amount of expert manpower. In New Zealand, expertise exists within the New Zealand Oceanographic Institute, and in India in the National Institute of Oceanography and the Geological Survey. In the United Kingdom, expertise in the field of non-living marine resources exists in the Department of Geology, Imperial College, London.

ii) Technical Training. In Australia, the Department of Earth Sciences of the Australian National University has been working in the field of non-living marine resources; in New Zealand, the Victoria University of Wellington; and in the United Kingdom, the Department of Geology at Imperial College, London.

Summary of Recommendations

1. New areas or subjects for possible co-operation and/or complementing existing programmes are :-

a) Increased aggregate and placer exploration within the E.E.Z.s of Commonwealth nations of the region, particularly the larger nations in the case of placers.

b) Increased precious coral exploration in the S.W. Pacific and equatorial eastern Indian Ocean.

c) New phosphorite exploration on shallow submerged seamounts and within coral atolls throughout the study area, but particularly in the western equatorial Pacific.

d) New metalliferous sediment exploration in the S.W. Pacific, especially in the Lau Basin between Tonga and Fiji.

e) Increased manganese nodule exploration within the E.E.Z.s of equatorial Pacific nations, and cobalt rich manganese crust exploration on seamounts and submerged portions of islands in the pelagic western Pacific and eastern Indian Ocean.

2. Prospects for technical assistance and scientific co-operation in research, training and information dissemination are :-

a) Provision of technical consultants in the field of marine mineral resource exploration and evaluation, working both independently and attached to ongoing mineral exploration and evaluation methods for mineral prospects in the E.E.Z.s of Commonwealth countries of the region. Such consultants could be drawn from Australia, New Zealand, India and the United Kingdom, and relevant institutions are listed in the body of the report.

b) Provision of training courses in non-living marine resources within the region, and the training of selected personnel in University departments abroad. Examples of existing courses and overseas training opportunities in non-living marine resources are listed in the body of the report.

c) Strengthening of information centres in India and Fiji, and possibly establishing a new one in the middle of the region.

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REMOTE SENSING

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1. INTRODUCTION

Remote sensing, the technique of acquiring information about objects, areas or phenomena by means of sensors mounted on aircrafts and spacecrafts is proving to be of great potential value for Earth resources survey applications. Remotely sensed data in conjunction with complementary and supplementary information derived from in situ observations enable assessment of renewable and non-renewable resources such as identification and yield estimates of agricultural crops, mapping of forests, evaluation of water resource potentials, mineral exploration, cartography and land use mapping. However, operational use of remote sensing techniques as an integral part of the routine data gathering systems for most of the above applications is yet to be established firmly. Among the several reasons for this, the most important one arises from the complex character of the remotely sensed information. One has to reckon with the interplay of several diverse effects and parameters that include radiative transfer characteristics of the atmosphere, emission and reflection properties of a variety of land features and of water surfaces, radiation interaction with

sensor systems, effects of platform dynamics on the acquired information as well as influence of data processing and analysis on the information content. To be of practical utility, autonomous remote sensing program should necessarily embody acquisition of information through air borne and space borne sensors, supplemented by ground measurements, processing and analysis of the acquired data and finally interpretation using well established scientific principles leading to the quantification of the resource parameters of interest. There is a substantial research component in this entire effort primarily stemming from the necessity of improved understanding of the physical processes that govern the remote sensing technique.

The modular character of the technique permit the countries to adopt this emerging technology in a phased manner starting with a few simple interpretative equipments and a few trained people. Subsequent phases could include more versatile processing and interpretative system, acquisition of data from air borne sensors and in the case of larger countries mounting their own integrated programmes including space segment. These steps would call for progressive increase in the investments of money and trained manpower besides setting up suitable organisational and operational structures.

As mentioned earlier, remote sensing as a technique is still in its infancy. Capabilities and extent of adaptation

of this technology greatly vary between different countries. At the minimal level, many of the countries have data analysis and interpretation capabilities. Some of the countries have established ground systems for data reception from remote sensing satellites and also carry out aerial surveys. A small number, own or plan to have their own space segment. It is thus clear that from the scientific, technological and application point of view remote sensing offers unique opportunities for international cooperation. Such cooperation and collaboration could range from carrying out joint research work on several scientific problems of relevance to remote sensing, sharing of the know-how on the technology of equipments used for interpretation of remote sensing data, making available satellite data acquired by a ground station to the neighbouring countries as an element of regional cooperation, share the experiences regarding the issues relating to the integration of remotely sensed data with the conventional data systems, to evolving a coordinated approach relating to compatability of techniques and technology, equitable access to data and analytical services.

As an association of 48 independant countries pledged to consult together and cooperate in the interest of peace, development and understanding, commonwealth represents a unique example of unity among nations with diverse social, economic and cultural backgrounds. Between them, these countries represent a quarter of the world's population

(about a billion people), occupy 18 % of the world's land surface, and posses rights over 6 mi. square Km of the economic zone of the world's oceans. The area of member states range from continental sizes as in the case of Australia (7.7m sq. km), Canada (9.98m sq. km) and India (3.3m sq. km) to small islands (Maldives 300 sq. km, Nauru 21 sq. km). Many of the countries of commonwealth are rich in mineral and other geological resources as yet untapped, some are leading producers of agricultural products and a small number belong to the industrially developed class. The diversity in the standards of income and living is easily comprehended by comparing per capita GNP for different countries, that vary from $ 5000 - 10000 (1980 figures) for countries like Canada, Australia and Britain to figures of the order of $ 200 - 500 for a large number of commonwealth countries. Against this backdrop of techno-economic diversity, institution of a frame work for a cooperative program in remote sensing, that has direct relevance to the development appears appropriate.

2. COMMONWEALTH CAPABILITIES IN REMOTE SENSING

As a subset of the global efforts to develop and exploit the technique of remote sensing, many countries of commonwealth have ongoing programs in this area, the scale of efforts ranging from modest to more ambitious. Most of the countries have programs that involve utilization of the aerial imageries and in some cases space imageries and employ

visual interpretation techniques. A fewer member of countries have set up a satellite data receiving station to enable access to the lands from satellite altitudes. Only three member countries of commonwealth i.e. Britain, Canada and India have presently capabilities for designing and building a space segment. Table 1 illustrates the spectrum of capabilities and resources available among commonwealth member states. The Table does not include all countries of the commonwealth, but serves to highlight the fact that between these countries, the entire range and scope of efforts encompassing simple visual interpretation, digital processing, aircraft based surveys, satellite data acquisition and processing as well as design, deployment and operation of a space segment are covered. Fig. 1 shows the location of Landsat ground stations within member states of commonwealth and those ground stations outside commonwealth, but having ground coverage of commonwealth member states. It is clear from the figure that many of the commonwealth countries are within the radio-visibility zone of one or the other Landsat ground stations and some of them possess their own.

3. PROSPECTS FOR COOPERATION IN REMOTE SENSING

Against the background provided in the foregoing pages, it emerges that there is considerable scope and potential for embarking on collaborative or cooperative efforts relating to one or more aspects of the remote sensing. Such effort could

be both of short term and long term nature and the scale of efforts will be essentially dictated by the available financial resources. As a short term goal, there are several possibilities that include conduct of workshop on specialised topics, conduct of end-to-end experiments as a part of establishing competence, education and training, sharing of experiences in solving a specific problem with remote sensing technique, transfer of technology relating to equipments used for interpreting data extending software support for data analysis and interpretation and joint work on relevant research problems. Such cooperation could be between a developed member with a developing member of commonwealth or between two developing members. A limited elaboration of some of the above possibilities are given below :

3.1 Conduct of Workshop

There are several specialized topics of direct relevance to remote sensing on which workshops could be organised. Such workshops besides providing a useful platform for indepth discussion of the techniques and methodologies could also serve the needs of the participants in getting experience in the solution of concrete problems, if organised properly. Some of the possible topics include photointerpretation techniques, digital processing of remotely sensed data, use of remote sensing data for specific applications such as agriculture, geology, forestry and land use. These workshops

could be of 4 to 6 weeks duration and could be conducted in the institutes or centres of remote sensing within the member states by specialists available within the commonwealth or from outside.

3.2 End-to-end Experiments

The purpose of remote sensing is served if the data acquired is analysed and interpreted with other supplementary/ complementary information to provide quantified resource parameters that could be ultimately used by resource managers or planners. The end-to-end concept of an experiment envisages such an ultimate goal for a particular thematic application. The experiment starts with the identification of a specific application goal followed by assessment of the basic data needs. The data may include those to be collected by aerial surveys and satellites supplemented by ground truth data collection through in situ observations and other auxiliary information. The next step involves adopting suitable processing and analysis techniques, either manual or composites aided. These results, suitably interpreted are presented in the form of thematic maps or such other outputs that are directly usable by the planner/decision maker. An exercise of this kind can help a country interested in getting initiated into the use of remote sensing for a specific application to derive the much needed experience in the methodologies of data collection, analysis and interpretation.

Parallelly, it could assist in the establishment of requisite infrastructure and specialised manpower. The assistance to plan and conduct such an experiment could come from a member country, having the requisite expertise. Transfer of know-how in terms of the hardware/software elements used in the experiment is implied in such a cooperative effort.

3.3 Education and Training

A variety of possibilities are conceivable as a part of education and training in remote sensing. Firstly, evolving of suitable curriculum for teaching remote sensing in universities and other educational institutions can be assisted by some commonwealth member states to others desirous of introducing remote sensing in the education. Secondly, courses can be also formulated and offered by developed countries to developing ones. Courses should cover subject matter such as basic matter and energy relationships, remote sensing capabilities in various parts of the electromagnetic spectrum, multistage sampling techniques, photo-interpretation, digital data processing and general issues related to the dissemination and use of Earth resources data for resource purposes. Thirdly, short term training can be offered at the remote sensing centres in commonwealth countries through the active support of commonwealth science council. Such training could enable the trainees to derive on line experience in the various facets of the remote sensing technique applicable to

various applications. Fourth possibility is the institution of fellowships under the aegis of commonwealth science council to enable active workers in remote sensing of commonwealth countries to spend a few months upto a year in centres of excellence, both within commonwealth and outside working on advanced techniques of remote sensing. A fifth possibility is support for research in specific areas such as those related to the identification and use of appropriate data for studies related to agricultural yield forecasting, soil mapping and hydrological resources which is of common interest to many countries using remote sensing techniques.

3.4 Transfer of Technology and Techniques

One of the major problems facing many of the developing countries in the speedy utilization of the remote sensing technology is the nonavailability of the interpretative devices that could enable them to carry out photo-interpretation of the aerial/satellite imageries. Such instruments include densitometer, additive colour viewer, microfische camera system, aerial film drier, mobile photo processing van and light table with coordinate measuring system. Additionally, for ground truth collection, instruments like radiometers and chlorophyll scanners are essential. Setting up of suitable mechanisms to transfer the know-how from the countries who posses the technology to those that do not is a possibility worth exploring.

3.5 Data Acquisition from Satellites

As shown in Fig. 1 and summarised in Table 2, i.e. large number of member states of commonwealth are within the visibility zone of one or more of the existing Landsat ground stations. Some of the member states possess their own ground station. Suitable cooperative arrangements need to be established to ensure continuous availability of satellite data for these countries that do not have ground stations themselves, but lie within the visibility zone of one of the existing stations. Further, the member states either totally or partially owning a space segment could make available opportunities for data acquisition to other countries of commonwealth through their satellites. Suitable mechanisms could be instituted for this purpose.

4. LONG TERM PERSPECTIVES

The short term possibilities identified earlier are tasks that could be undertaken and accomplished in the time frame of 1 - 5 years. Based on the experience from such short term efforts, a viable long term plan can be evolved. One important possibility in this context concerns the establishment of a Commonwealth Remote Sensing Centre (CRC), that could serve as a focal point for discharging many of the functions spelt out under the short term objectives. Such a Centre will have a minimum basic infrastructure for training and education

in remote sensing, organising workshops on specialised topics and promoting advance research in relevant areas, besides serving as a clearing house for information on remote sensing activities carried out elsewhere in the world. As a long term perspective, such a Centre could also promote bilateral/ multilateral consultation among member states on technical and managerial aspects of remote sensing related to the planning of ground stations, space segment and aerial aspects of remote sensing. Such a process of consultation can facilitate sharing of experience, standardisation of product formats besides providing a platform for discussion of common problems.

Elements of short term goals are expected to evolve and integrate themselves in 3 to 4 years so as to lead to this long term goal in a concrete fashion.

TABLE-1

REMOTE SENSING APPLICATION CAPABILITIES AMONG SELECT COMMONWEALTH COUNTRIES

Country	Photo interpretation	Digital Processing	Aerial Surveys	Ground systems for Satellite data acqn.	Space Segment Capability	Specific application Projects	Education & Training
1. Canada	Facilities exist for rapid delivery of Quicklook photographic products of LANDSAT. Good overall capability exist in this area.	-Produces as a standard Product digital image data in a precision form to exactly overlay standard maps -Capability exists for digital processing of radar data (SEASAT) Good overall capability exist in this area.	Long experience exists especially for forest monitoring and transportation engineering.	Two Landsat ground stations exist. Four provincial remote sensing centres exist.	Initiated studies for definition of SAR program.	-Participated in SEASAT program to gain experience in use of radar data. -Experiments covered several application areas like geology, water resources, forestry, agriculture, land use planning, environmental impact studies, wild life habitat studies, oceanography, ice reconnaisance and pollution studies. -Successful/specific applications include geological exploration of gypsum and uranium, ice reconnaisance and monitoring logging activities in forestry.	CCRS, as a federal agency, provides support . Many federal and provincial agencies, institutions and facilities, coordinated at national level, provide the support for education and training. In addition universities offer regularly scheduled courses. Specific programs include Digital work shops of CCRS, remote sensing courses of ARSC, QRSC, Geological Survey of Canada and the Post Graduate courses of Laval University in Quebec.
2. Australia	Photographic product generation facilities available for LANDSAT. "Browse Centres" exist in each state where users can examine quicklook imagery.	Capabilities exist and developments undertaken for enhancement and classification of Multispectral data from LANDSAT.	Used for experimental studies like assessement of potato cropping using infrared imagery.	Landsat receiving station exists at Alice springs and a processing centre in Canberra.	Preparing to launch two satellites in the current decade.	-Agriculture crop area monitoring and production with major emphasis on Wheat. -Vegatation classification: Besides these, many specific projects and studies are conducted in the areas of Land inventory and assessment, range lands management, Forest resource assessment, Mineral exploration, water inventory and assessment, Atmosphere-land interface, surveying and mapping, atmospheric pollution, pelogic and open-sea ecosystems, pasture monitoring.	Facilities and involvement available from CSIRO and a number of Australian universities.

Country	Photo Interpretation	Digital processing	Aerial Surveys	Ground systems for Satellite data acqn.	Space segment capability	Specific application projects	Education and Training
3. Bangladesh	Analysing facilities available for visual systems.	Automatic data processing capability exists. A digital processor is planned for installation.	Aerial photographic data are gathered and Aircraft capability exist.	Arrangements being made to install high resolution APT & GMS ground station systems. Facilities exist for low resolution APT & GMS systems. A Landsat-D/SPOT ground station is planned for establishment.	-	Land accretion study through LANDSAT; Baseline map of Bangladesh Coast; Land use Association map; Rice crop inventory; geological feature atmospheric studies and meteorological applications.	Provided through external seminar workshop participation.
4. India	Full pledged facilities available. Many low-cost aids have been developed for data analysis and interpretation.	Both computer, Hardware and software capabilities exist. for processing visible, Near IR data. Developments are underway for processing radar data.	Aircraft capability as well as the sensor capability exist for photographic, multispectral & side-looking airborne radar surveys.	LANDSAT receiving station available and is planned to upgrade this for data reception from SPOT In addition, data reception handling & processing systems have been established to support Indian satellites.	Experimental satellites like Bhaskara I & II, have been developed and launched, carrying 2 band TV camera systems & passive microwave radiometers. The Indian Remote Sensing Satellite system carrying multiband CCD cameras is under development.	A number of operational resource survey has been carried out covering agriculture (land use, crop census, disease detection), Geomorphology, surface water & ground water resources, Mineral resources and forestry environment. Traditional photogrammatic applications covered areas of cartography, geology, forestry & hydrology.	Facilities available for training in photo interpretation and other application techniques at Indian Institute of Remote sensing. Education & Training activities are also conducted through the involvement of Department of Space & Education Institution through workshops, seminars & other courses.
5. Britain	Capabilities exist	Capabilities exist	Capabilities exist both for Aircraft and sensors.	Member of ESA's EARTH-NET and SEASAT data pre-processing occurs at Farnborough where a national Research centre is being developed.	As a member of ESA, Contributes to ESA's remote sensing program which includes a full pledged space-segment.	Projects covering several application areas are undertaken.	Provided by various Govt. Depts laboratories & universities, land resources division of Ministry of over seas Dept. provides short courses for students from developing countries.

Country	Photo interpretation	Digital processing	Aerial Surveys	Ground systems for satellite data acqn.	Space segment capability	Specific application projects	Education & Training
6. Newzealand	Basic facilities exist	Basic facilities exist	Multispectral surveys have been conducted.	The need for a local earth resources satellite receiving station to acquire data from LANDSAT & other earth resources satellites is under assessment.	-	Research studies have been carried out relating to land use involving LANDSAT data and through a package of interactive computer programs.	Education & training activities provided by university of Auckland & physics and Engineering Laboratory.
7. SriLanka	Photographic processing of black & white enlargements, multiband composites and 3-band colour composites are available.	CCD processing capability with general purpose computer available.	Aircraft capability exists.	It is proposed to establish a LANDSAT data receiving station.	-	Experiments have been conducted using satellite data for Land use mapping, forestry, geology, rice yield forecasting, monitoring of irrigation reservoirs and water distribution for large scale agricultural areas.	In-service training for resources evaluation is planned to be provided by remote sensing section of survey of Srilanka.
8. Malaysia	Facilities exist & have been used for analysing LANDSAT and aerial photographs.	Facility is very limited.	Conventional low-medium altitude aerial photography techniques have been used.	-	-	Mapping & resource evaluation programs using aerial photography, mainly involving land, forestry & agricultural resources.	Provided through external seminar/ workshop participation. Plans are underway for training, organising by National Remote Sensing committee & academic institutions
9. Kenya	Capability exists. Suitable optical analysis equipment is available in Govt. agencies and Regional Remote sensing facility.	External facilities are used.	Aircraft capability exists.	Plans for establishment of Earth Resources satellite Ground receiving & processing station at Nirobi.	-	The several application projects included crop detection, soil survey, habitat mapping, forest mapping, geological mapping, disease & pest detection in plantations, coastal environment and oceanographic studies, cartography and demography.	University of Nirobi offers regular courses. The regional Remote Sensing facility also offers Training and user assistance programs. Local workshops and symposia are also organised.

Country	Photo interpretation	Digital processing	Aerial surveys	Ground systems for satellite data acqn.	Space segment capability	Specific application Projects	Education & Training
10. Nigeria	Visual interpretation facility only. Photographic reproduction facility and cartographic capability available.	Not available	Aerial photography is being carried out as part of a detailed mapping program of Geological survey.	Not available.	-	Remote sensing data is applied in several application fields to derive information on arid zone afforestation, erosion control, fire protection, forestry wildlife and geological mapping.	Regional centre for training in Aerial surveys exist at Ile-Ife, which also trains users in photo interpretation cartography and photogrammetry.
11. Uganda	Black & White photo laboratory available.	Not available	Aerial photography is carried out. Cameras and plotting equipment available.	Not available.	-	Aerial photography is applied to mapping and cartography;& LANDSAT pictures were used to map the soil vegetation and geology.	Education & training is provided through external sources and also through universities.
12. Botswana	Photographic reproduction and cartographic capability available.	Not available	Aerial photographs available.	-	-	Application projects undertaken include Land use mapping, geological survey, hydro-geological interpretation, heat capacity mapping and photo geological mapping.	Provided through external seminar/ workshop participation.
13. The Gambia	Not available	Not available	Available	-	-	The specific application project using air-photography was in the area of land resources mapping.	-
14. Ghana	Cartographic capability & photographic reproduction available.	-	Aerial photographs available.	-	-	-	Provided through external agencies for users.
15. Jamaica	Photographic reproduction & cartographic capability exists.	-	Aerial photographs available.	-	-	-	Provided through external seminar/ workshop participation.

Country	Photo interpretation	Digital Processing	Aerial Surveys	Ground systems for satellite data acqn.	Space segment capability	Specific application projects	Education & Training
16. Lesotho	-	-	Aerial photographs available.	-	-	Landsat imagery interpretation used in fracture analysing study to assist in location of Kimberlite intrusions.	Provided through external seminar/ workshop participation.
17. Malawi	-	-	Aerial photographs available.	-	-	-	- None -
18. Sierra-leone	-	-	Aerial photographs available.	-	-	-	Provided through external seminar/ workshop participation
19. Tanzania	Photographic reproduction and cartographic capability exists.	Automatic data processing capability exists.	Aircraft capability exists.	-	-	Landsat data was used for land resources assessment and water resources management information. Aerial photography was also used for deriving land-use in a region.	Provided through external seminar/ workshop participation.

Table - 2

LANDSAT COVERAGE FOR COMMONWEALTH COUNTRIES

Country	Receiving station and average detail.	Location of receiving station	Receiving station is Commonwealth country or not
Antigua and Barbuda	Partly visible to Greenbelt, Maryland for Landsat 1, 2 and 3. Not visible for Landsat D & D'	Maryland in U.S.	No
Australia	Totally visible from Alice springs, Australia.	In Australia	Yes
Bahamas	Totally visible from Greenbelt, Maryland.	In U.S.	No
Bangladesh	Totally visible from Hyderabad, India	In India	Yes
Barbados	Not visible	-	-
Belize	Visible from Greenbelt for Landsat 1, 2 and 3 and not visible for Landsat D & D'.	In U.S.	No
Botswana	Totally visible from Johannesburg.	In S.Africa	No
Great Britain	Totally visible from Kiruna and from Fucino	Kiruna in Sweden ‖ Fucino in Italy ‖	No
Canada	Visible from Prince Albert, Fairbanks, Goldstone, Shoe Cove, Greenbelt.	In U.S. & Canada	Prince Albert ‖ and Shoe Cave ‖ Canada - Yes
Cyprus	Fucino (Totally visible)	Italy	No
Dominica	Not visible	-	-
Fiji	Not visible	-	-
The Gambia	Not visible	-	-
Ghana	Not visible	-	-

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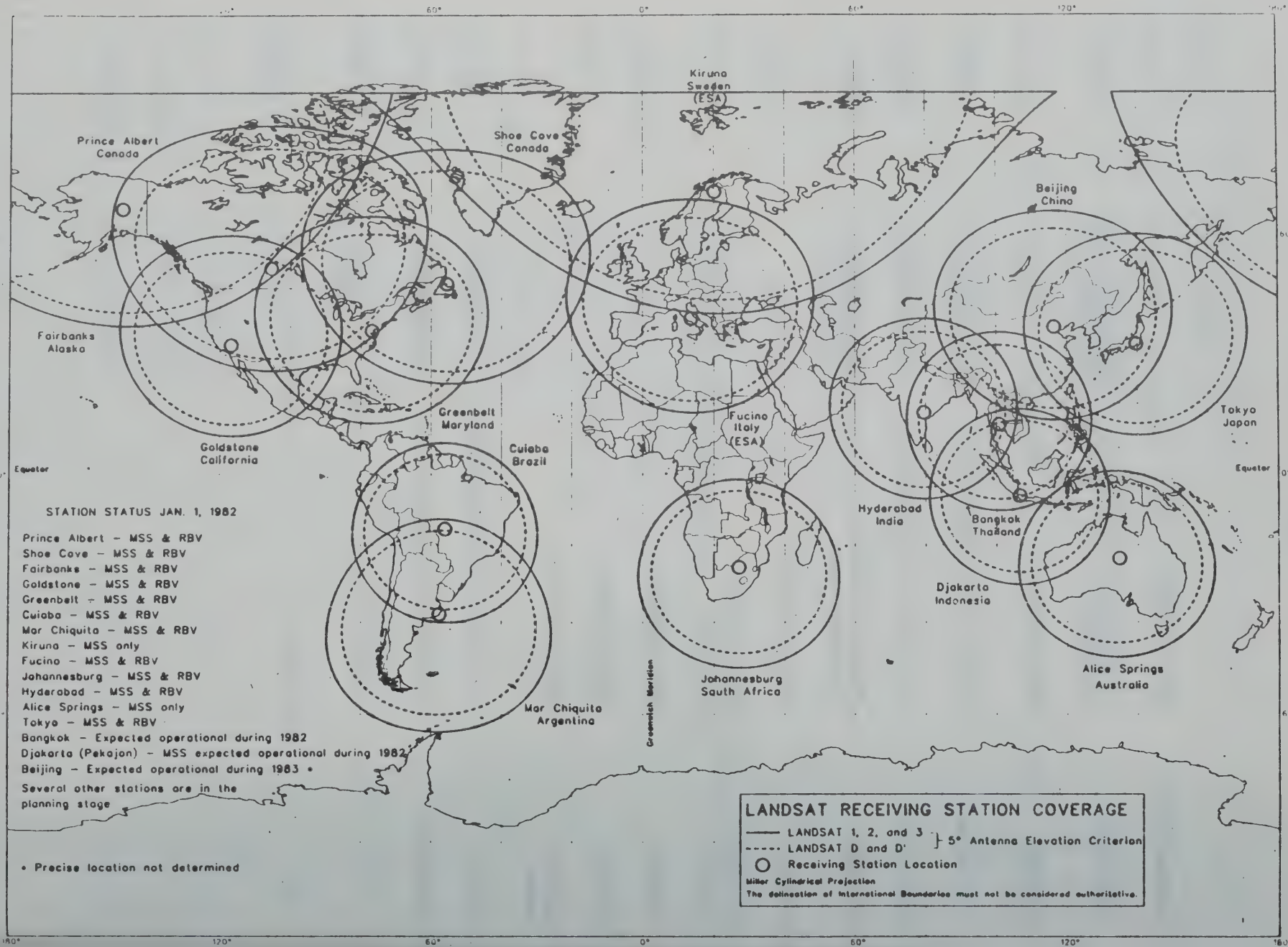
Greneda	Not visible	-	-
Guyana	Visible to Cuiaba	In Brazil	No
India	Totally visible from Hyderabad, India	In India	Yes
Jamaica	Visible to Greenbelt.	In Maryland, USA	No
Kenya	Partly visible to Johannesburg	In S.Africa	No
Kiribati	Not visible	-	-
Lesotho	Totally visible to Johannesburg	In S.Africa	No
Malawi	-do-	-do-	No
Malaysia	Visible to Djakarta, Bangkok, Hyderabad(Partially)	Indonesia,Thailand and India	No Yes
Maldives	Visible to Hyderabad	India	Yes
Malta	Totally visible to Fucino.	In Italy	No
Mauritius	Not visible	-	-
Nauru	-	-	-
New Zealand	Not visible	-	-
Nigeria	Partly visible to Fucino	In Italy	No
Papua New Guinea	Visible to Alice Spring	In Australia	Yes
St. Lucia	Not visible	-	-
St.Vincent	Not visible	-	-
Seychelles	Not visible	-	-

Sierra Leone	Not visible	-	-
Singapore	Visible to Djarkata, Bangkok.	Indonesia and Thailand	No
Solomon Islands	Not visible	-	-
Sri Lanka	Visible to Hyderabad.	In India	Yes
Swaziland	Visible to Johansburg.	In S.Africa	No
Tanzania	Partly visible to Johannesburg	In S.Africa	No
Tonga	Not visible	-	-
Trinidad & Tobago	Not visible	-	-
Tuvalu	Not visible	-	-
Uganda	Not visible	-	-
Western Samoa	Not visible	-	-
Zambia	Visible to Johannesburg	In S.Africa	No
Zimbabwe	Visible to Johannesburg.	In S.Africa	No

FIGURE 1


Kiruna
Sweden
(ESA)
Prince Albert
Canada
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China
Fairbanks
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Greenbelt
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Goldstone
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Thailand
Djakarta
Indonesia
Johannesburg
South Africa
Alice Springs
Australia
Mar Chiquita
Argentina
Greenwich Meridian
STATION STATUS JAN. 1, 1982
Prince Albert – MSS & RBV
Shoe Cove – MSS & RBV
Fairbanks – MSS & RBV
Goldstone – MSS & RBV
Greenbelt – MSS & RBV
Cuiaba – MSS & RBV
Mar Chiquita – MSS & RBV
Kiruna – MSS only
Fucino – MSS & RBV
Johannesburg – MSS & RBV
Hyderabad – MSS & RBV
Alice Springs – MSS only
Tokyo – MSS & RBV
Bangkok – Expected operational during 1982
Djakarta (Pekajon) – MSS expected operational during 1982
Beijing – Expected operational during 1983 •
Several other stations are in the planning stage
• Precise location not determined
LANDSAT RECEIVING STATION COVERAGE
LANDSAT 1, 2, and 3
LANDSAT D and D'
5° Antenna Elevation Criterion
Receiving Station Location
Miller Cylindrical Projection
The delineation of International Boundaries must not be considered authoritative.

REMOTE SENSING - SOUTH PACIFIC EXPERIENCE

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1 INTRODUCTION

This brief review of earth resources remote sensing in New Zealand and the South Pacific has been prepared for the Commonwealth Science Council to assist in the formulation of an expanded programme of scientific co-operation.

New Zealand became involved in satellite remote sensing soon after the launch of Landsat 1 in 1972. The potential utility of environmental satellite data was the spur to setting up a remote sensing section within the Department of Scientific and Industrial Research, with the role of co-ordinating a programme of research into satellite image processing and interpretation. The intervening years have seen a substantial growth in understanding of the technology and of the range of problems which could benefit from the availability of remote sensing data.

These early co-operative activities, including a formal investigation programme using the Landsat 2 satellite, had the effect of creating a group of users in different earth science disciplines, who were all able to utilise the developing processing and interpretative facilities, and to discuss the successes and failures in each project. All the projects associated with the Landsat 2 investigations have been described in a publication which evolved out of the final report to NASA (Ellis et al. 1978).

The studies in New Zealand have involved many disciplines, including agriculture, forestry, fisheries, geology, hydrology, oceanography, cartography, land use and coastal studies. Several projects have been conducted in Antarctica, and in some of the islands in the South Pacific, including a study of the reefs in the Lau Islands (part of the Fiji group), and a project to enhance imagery of Western Samoa. In many of these more remote islands, remote sensing programmes do not exist, and the co-operative projects with New Zealand have been the first introduction to the potential of this technology.

As far as is known at present, the only formal education offered in remote sensing within the South Pacific region is the course of studies at the Geography Department of the University of Auckland. Post graduate work in image processing and remote sensing is conducted at the University of Waikato near Hamilton in the North Island. The Auckland group are also actively engaged in image analysis, and have strong links with the remote sensing groups in Californian universities. Digital image processing related to remote sensing is the subject of undergraduate courses and post graduate work in the Electrical Engineering Department at the University of Canterbury in the South Island.

Commercial and industrial interest in remote sensing has so far been limited to minerals and petroleum exploration companies, with indications of support for a future operational remote sensing system from companies associated with agriculture, forestry and fishing.

Even at the present limited level of activity, the benefits of participation in remote sensing technology are beginning to appear. Software developed at the Department of Scientific and Industrial Research is now being marketed internationally, and one instrument, a radiometer designed by the same group is being commercially made, and will be flown on the Space Shuttle in 1984.

This paper summarises the progress made in this emerging branch of science, and puts forward some suggestions for enhancing co-operation with other Commonwealth countries.

2 BACKGROUND

2.1 New Zealand

The two main islands and the outlying islands have a combined area of 26.9 million hectares, of which less than one quarter lies below the 200 m contour. The coastline is approximately 9000 km long, and the surrounding Exclusive Economic Zone is one of the largest in the world, with an area of about 4.2 million sq km.

The main islands lie between latitudes 34 deg and 47 deg south, and longitudes 166 deg and 179 deg east. The average rainfall varies between 250 and 4000 mm, with large local variations. Mean annual temperatures vary from 15 deg C in the north to 12 deg C in the south, with an annual range of about 8-10 deg C.

The population in 1982 was 3.2 million, of which over 70% live in the North Island.

In the past, the economy has been largely agricultural and pastoral, but more recently other primary industries such as forestry, horticulture and fishing have gained in prominence, with rapid developments also in the manufacturing sector. However, the economy still depends to a great extent on agriculture, which in 1982 accounted for 56% of the total export trade of $6,734 million. Other major categories were wood and manufactured forest products at $293M, fish at $153M, manufactured items at $1058M, mineral and chemical products at $327M, and horticultural products at $117M.

2.2 Pacific Island Groups

The South Pacific islands with the greatest links with New Zealand include the Fiji group, Western Samoa, Tonga, and Cook Islands and Niue. The total population is around 800,000.

The major exports are sugar, coconut products and bananas.

The largest land area is in the Fiji group, with 10,947 sq km, followed by Western Samoa at 2935 sq km, Tonga at 697 sq km, Niue at 259 sq km and the Cook Islands at 240 sq km. Distances between population centres are very large by European standards, and are an inhibiting factor in economic development of the region. For instance, some typical distances are: New Zealand-Fiji 2099 km, New Zealand-Cook Islands 2988 km, Fiji-Western Samoa 1183 km, Western Samoa-Cook Islands 1402 km. Most of the island groups consist of two or three main islands and numerous smaller islands. In nearly all cases, the islands are surrounded by reefs.

2.3 Antarctica

Scott Base, New Zealand's permanent base in Antarctica, was established in 1957. Up to 300 personnel are housed at Scott Base and the outlying stations of the Ross Dependency during the summer season.

The Ross Dependency Research Committee is responsible for formulating the Antarctic research programme. Landsat scenes of the region have been combined with topographical data to produce very effective maps, used mainly by aircrew operating local aircraft.

3 TECHNOLOGY

3.1 Data acquisition

The Landsat programme has been the source of most of the data used by several centres in New Zealand for remote sensing development work. From 1975 to 1977, fairly regular coverage was achieved during the Landsat 2 investigation programme. With the subsequent decline of the availability of images from the on-board tape recorders, few scenes have been received, and none since 1981.

Ocean and coastal studies have been aided by sporadic coverage from the Coastal Zone Colour Scanner (CZCS) aboard Nimbus 7. CZCS images are currently being received from NOAA in the USA, and from the Australian receiving station at Orrorral near Canberra.

Data from the Advanced Very High Resolution Radiometer are received daily at the New Zealand Meteorological Service, and selected scenes are archived at the PEL remote sensing section. AVHRR data is restricted in earth resources applications by its limited ground resolution of 1 km.

The four channel multispectral aircraft camera developed at PEL has now been transferred to a commercial mapping company, New Zealand Aerial Mapping. A second identical camera is now in operation with the remote sensing section of the Ministry of Works and Development (Stephens et al. 1981). These agencies both offer a service in false colour and multispectral photography. Interpretative facilities including a colour additive viewer are available at MOWD.

In 1980, a ten channel aircraft scanner was hired from a company in the US for six weeks in summer, during which time 35 surveys were conducted for 12 different agencies (Cresswell, 1982). These included government departments, universities, local authorities and industries. For the first time, images in digital form were available at a range of ground resolutions from 1 metre to 10 metres. Scenes at 10 metre resolution have been compared with scenes from Landsat MSS at 80 metres resolution, giving an indication of the benefits which might be expected from the new generation of high resolution satellites (Timmins et al. 1983).

Increasingly, data from sources other than imaging sensors are being used in combination with remotely sensed images, or in the production of artificial images. The PEL archives now hold a 1000 m grid digital terrain model of the country, prepared by the DSIR Geophysics Division, a selection of soil survey files from the DSIR Soil Bureau and a library of control points used in the rectification and mosaicing of images (Crayford and McDonnell, 1982). Other products include digitised graphics files of the New Zealand coastline, rivers, lakes and state highways as well as contours of some regions (McDonnell, 1982, 1983).

3.2 Image processing

The remote sensing section at PEL was, until recently, the only organisation with the capability to process remotely sensed images by computer. The only other group working in a similar field was the image processing research group at the Electrical Engineering Department of the University of Canterbury.

The remote sensing group at the Geography Department of the University of Auckland has had a long history of association with the remote sensing group at the University of California, Santa Barbara, with access to the interactive analysis laboratory.

Development of image processing at Waikato University has now reached the stage where the large software package produced by the PEL group is being implemented. Several postgraduate projects involving image processing are in progress (Chalmers and Harris, 1981; Chalmers, 1982).

At PEL, image processing is centered on two computing systems, the general purpose VAX and a dedicated LSI 11/23 in the laboratory. An interactive display system, designed and made in the section, permits the user to scroll through a satellite or aircraft image, and to make use of any of the many enhancement options. Once a satisfactory result has been obtained, the full scene can be generated at a very high resolution, and in colour, on the Optronics Colorwrite machine (McDonnell, 1984). A small photographic darkroom facility is equipped to process the transparencies from the Colorwrite, and to produce a variety of prints and copy transparencies.

The range of software options available to the user is large, and includes several methods of colour enhancement, image classification by supervised clustering, rectification to fit any of the standard map projections, edge enhancement by convolution techniques, mosaicing, and overlaying of image planes, for instance, to combine topographic line data with a Landsat scene (McDonnell and Pairman, 1983).

In addition to these standard procedures, specialised programs are available for Fourier transformation, image restoration, superresolution and modelling colour space.

3.3 Instrument development

Apart from design work associated with the image processing facility, most of the instrument development work has arisen from a need for specialised devices to acquire data in support of the image analysis program.

For five years, a series of contracts have been awarded by DSIR to the image processing research group at the University of Canterbury to develop imaging instruments based on Charge Coupled Devices (CCDs). A CCD scanner has been successfully flown on aircraft trials (Hodgson et al. 1982), and a large format version is being produced for digitising images within the laboratory.

At PEL, a field spectrometer with digital data storage facility has been developed for use in the study of spectral reflectances of remotely sensed targets. The aim is to produce a data base of spectral signatures to assist in the evaluation of future projects and to enable the choice of spectral passbands to be made more scientifically.

The eight channel radiometer (Ellis and Nankivell, 1983) designed at PEL arose out of our experiences with radiometers used during ground truth studies. At the time this project started, the available radiometers suffered from several disadvantages. It was believed that recent developments in device technology made possible a smaller, more stable instrument, with a sufficient number of channels to simulate those used in the new generation of satellite sensors, such as the Thematic Mapper on Landsats 4 and 5.

Because of the perceived range of uses for this instrument, and the success in meeting the design criteria, an agreement was made with Delphi Industries of Auckland to conduct a market survey, with a view to manufacturing and marketing the radiometer and its derivatives. Initial sales are being made in Europe, the USA, Australia and New Zealand. One of the first instruments to be sold will be flown on the Space Shuttle in 1984, in support of the programme of oceanographic studies.

4 APPLICATIONS OF REMOTE SENSING

4.1 Agriculture

Because of the dependence of New Zealand and the Pacific Islands on agriculture, several projects have been conducted to determine the accuracy of crop identification and the ability to detect stress, due for instance to a lack of water or to disease. Most of these trials have been centered on the Canterbury Plains, one of the principal arable farming areas, around the small town of Darfield. The results show that Landsat MSS data can be used to classify the major categories of crops, cereals, pasture or bare ground, to better than 85% accuracy, but that classification to a more detailed level may require imagery taken at a very specific stage of the cropping cycle. The Landsat classification project suffered from a lack of imagery, with only one image acquired during late spring of 1975. Subsequent trials with an aircraft multispectral scanner, conducted in midsummer, have shown that the following classes can be accurately mapped using a maximum likelihood classification method: wheat, barley, all cereals, peas, dry pasture, green pasture, fallow, trees and scrub (Ellis et al. 1982).

The detection of moisture stress in cropping areas has so far been limited to visual interpretation over a large region. Regional variations of moisture have been correlated with moisture levels measured by other methods in the Canterbury Plains, and good agreement obtained.

4.2 Forestry

The present investment in plantation forestry in New Zealand is estimated at $3 billion. Landsat and aircraft scanner imagery has been used in projects to determine the feasibility of conducting an inventory of native and exotic forests, and to detect stress due to disease and windthrow. Although total forest areas can be identified, classification of tree type and maturity within the indigenous or exotic forests has had limited success. The major impact of satellite remote sensing is seen as a management tool for year to year operations monitoring, and as a means to map the whole country in a cost effective manner.

The forest classification analyses were made using the IBM ERMAN classification software, at the IBM Centre in Sydney, Australia, and a total of three Landsat scenes (Ching, 1982).

Two areas were covered, the King Country region of indigenous forest west of Lake Taupo in the North Island, and the Eyrewell State Forest in the South Island. The study area in the King Country was 16,400 sq km, and estimates of the cost and manpower savings over conventional ground and aircraft surveys were 82% and 93% respectively. In the indigenous forest, classification was divided into five fairly broad groupings of tree types, plus scrub, exotic forest, urban and bare ground. The average probability of a pixel being classified into its correct class was 81.9%. The Eyrewell State Forest consists of blocks of exotic trees of different types and ages. When the trees were grouped by age into three year plantings, the classification probability was 86.7%.

Serious wind damage was evident in the Eyrewell Forest, and this was well defined by the classifier. Earlier attempts to detect a fungus disease, dothistroma, in conifers of the Kaingaroa State Forest had failed, and no other attempts at disease detection have been made.

4.3 Land cover mapping

The IBM ERMAN classification system was used by the Department of Lands and Survey to investigate the accuracy with which a region could be classified into the major land cover categories (Benning 1982). The region chosen was the King Country because of the current interest in redevelopment of the area. Eleven classes were appropriate for this study, and these were: high vigour pasture, developed rangeland, undeveloped rangeland, land reverting to scrub, ferns, scrub, forest, tussock grass, urban/bare ground, wetlands and water. The probability of a pixel being classified correctly 999 times out of 1000 varied from 82.7% (wetlands) to 100% (water). A classification map was produced in colour for the King Country, overlaid by the cadastral (land tenure) boundaries. A high correlation was achieved between these boundaries and the class boundaries, showing the differences in farming practice.

Studies of vegetation cover in Northland, east Taupo, and Westland have been made by the remote sensing group at Auckland University (Cochrane and Batty, Strachan and Cochrane, Batty and Cochrane 1978). Another study of vegetation on Mount Tarawera used the parallelepiped classifier of the PEL remote sensing section, and achieved a probability of correct classification of 88% for 13 classes (Timmins, 1982).

4.4 Cartography

Cartographic applications of satellite images have been restricted by the limited ground resolution. Even so, the Department of Lands and Survey have used Landsat MSS images as a model in the production of hill-shaded maps and aeronautical charts, at scales of 1:250 000 and 1:500 000 (Thomas et al. 1978). The imagery has been of especial value in mapping remote areas such as Antarctica (Thomas and Nicholas 1981). The advent of the Landsat 4 Thematic Mapper, the Large Format Camera and the SPOT spacecraft, with resolutions down to 10 m, will open up many more applications in this discipline.

4.5 Geology

During the Landsat 2 investigations, the New Zealand Geological Survey conducted an analysis of lineaments in both islands. The mapping of major lithologic units was also found to be possible from the same images (Oliver 1978). Possibly the greatest feature so far of satellite data has been the synoptic view, which has enabled correlations between lineaments to be seen for the first time, and has resulted in the detection of some circular

features of between 10 km and 20 km in diameter (Thomas et al. 1981). These circles seem in some cases to be related to known mineral deposits, although the relationship is still far from clear. Two prospecting companies have used these images in their investigations in the vicinity of these features.

Another application has been the mapping of areas of ultrabasic rocks found in Northland, Nelson and South Westland (Brooks and McDonnell, 1983).

Because of the high vegetation cover over most of New Zealand, imagery in the visible and near infrared spectrum cannot be used to detect the fine topographic structure. This situation should be greatly improved with the coverage from the synthetic aperture radar aboard the Space Shuttle, expected later this year.

4.6 Hydrology and coastal studies

During the Landsat 2 investigations, the Auckland University group has analysed coastal turbidity and sediment flow around two areas of the North Island coast, and studied suspended sediment in Lake Taupo, New Zealand's largest freshwater lake (Campbell and Cochrane 1978). Thomas (1980) showed that repetitive Landsat data could be used to map the bottom contours of a tidal inlet.

Snow has been the subject of several projects in New Zealand and the Antarctic (eg, Thomas et al. 1978a). Some success has been achieved in differentiating between different types of snow and ice, particularly in Antarctica, and in mapping the projected area of snow in mountain areas. More work needs to be done to see if regular monitoring of snow cover can assist in predicting runoff in water catchment areas.

A current offshore study is concerned with a large circular eddy at the eastern end of Cook Strait. CZCS and AVHRR images have been used to monitor the variations in this eddy, and the associated sea surface temperatures. This project is continuing, and will utilise the synthetic aperture radar data as it becomes available (McDonnell et al. 1983).

Soil moisture is another variable of great importance in this agricultural country. Using data from the aircraft scanner, the variation of soil moisture in controlled plots at an agricultural research centre was monitored on the ground, and correlated with variations in the spectral radiances recorded in the aircraft images (Timmins and Fitzgerald, 1984).

5 THE PRESENT SITUATION

After ten years of satellite remote sensing in New Zealand, people are much more aware of the data and its interpretation, and of the type of applications which may derive benefit from operational sensors. All the computer enhanced imagery is available to the public through the district offices of the Department of Lands and Survey, and digital analysis projects are routinely conducted at PEL. Graduates with a background in remote sensing interpretation are emerging from Auckland and Waikato Universities, and aircraft multispectral surveys are operated from MOWD and New Zealand Aerial Mapping.

In the absence of timely data from any of the high resolution satellites, the problem at present is to maintain the momentum until this experimental science becomes a routine tool of the resource manager.

At PEL, a computer generated mosaic of New Zealand is being prepared from past Landsat images. Applications studies are continuing in geology, oceanography and resource mapping.

Recently, a national proposal was prepared by a group of user organisations under the guidance of the remote sensing section at PEL, to participate in the Shuttle Imaging Radar (SIR-B) experiment, planned for a Space Shuttle flight in August 1984. This submission was successful, and as a result, coverage of parts of New Zealand should be obtained for the first time with the Synthetic Aperture Radar. This has opened a new field in image processing and interpretation, and will help to fill the gap left by the lack of Landsat images.

By the end of the Landsat 2 programme, awareness of remote sensing and its applications had reached the point where the future was being discussed at Government level. To aid these discussions, an interdepartmental working group was set up to consider the benefits or otherwise which might result from a commitment to build a data receiving station, for the direct reception of earth resources satellite data. The group was made up of senior representatives of those departments with a potential interest in using the data from any future operational satellite systems. The final report of this group was submitted in 1982, and supports the concept of establishing a receiving station, although direct cost recovery, for instance by sales of imagery, is not seen as a possibility (Hickman, 1982). Rather, it is the less tangible benefits which outweigh these short term equations, related to the increased ability to monitor our agriculture, forestry, fishing and other major industries.

The current uncertainties surrounding the Landsat programme in the USA, and the unknown future costs of access to satellite transmissions, have tended to put a hold on decisions to invest in a receiving station. This is reinforced by the disparate cost/benefit ratio, when regarded as a short term investment requiring costs to be met by returns from sales. Thus at present remote sensing projects tend to be experimental only, with no immediate prospect of participation in the new satellite programmes.

6 CONCLUSIONS AND SUGGESTIONS FOR COMMONWEALTH CO-OPERATION

Most of the foregoing discussion has concentrated on the development of remote sensing within New Zealand. This is mainly due to the lack of activity in this discipline in those Pacific Islands with the greatest links with this country. Exceptions have been the projects in reef mapping in Fiji and Western Samoa. Papers discussing reef mapping in other parts of the Pacific have been published by the US Defence Mapping Agency.

6.1 Problems facing New Zealand and the Pacific Islands

6.1.1 Uncertainty of future costs and access to data

To be useful, remotely sensed data needs to be available soon after acquisition, and available at the right times of the year for the detection of change. In applications such as fishing, processed images are needed within hours or reception.

Satellite systems such as Landsat offer the possibility of rapid and regular access to data, but the current uncertainties in the move towards operational systems, and the final cost to the customer are inhibiting progress. A receiving station with the capability to receive from the new generation of sensors, and to process this imagery, will cost approximately $US10M at the current rates. This is a large sum for a small nation to find, especially if the cost cannot be offset by sales to adjacent countries. To the capital cost must be added the cost of access, currently $US650,000 per annum for Landsat, and likely to rise to a much higher level.

For a country of the size of New Zealand, requiring 100 scenes for complete land coverage four times per annum, the cost per scene will exceed $3000. Compare this with countries such as Canada, requiring in excess of 3000 scenes per annum with a correspondingly reduced cost per scene.

6.1.2 Dissemination of the technology

The high cost of digital image processing, and the high degree of expertise involved, reduces the chances of the technology becoming established in the smaller groups of Pacific Islands. Nevertheless, considerable benefits could be gained by the use of satellite imagery in for instance fishing, reef and island mapping, and generally monitoring the large offshore economic zones. The problem is therefore to demonstrate the utility of remote sensing, using local examples, and to provide the means by which these islands can get their imagery processed and analysed.

6.1.3 Spatial Resolution

In New Zealand and the Islands, remote sensing on land has been hampered by the small size of the target. For instance, in New Zealand the average field size in the Canterbury Plains is 9.6 ha, or about 20 pixels of the Landsat MSS. The new generation of high resolution sensors such as SPOT and the Thematic Mapper are therefore of especial interest. Unfortunately, the reception and processing of these data are more difficult because of the high data transmission rates, and the large volume per scene.

6.1.4 Keeping Up

Distance from the centres of technology such as Europe or the USA tend to inhibit the free exchange between scientists, and to discourage participation in high technology projects. This is a serious problem, and could result in a widening gap betwen even relatively advanced countries such as New Zealand and the rest of the industrialised world. There is a need to encourage investment in high technology within the South Pacific Countries. One way to create the right environment for this is to show that it is possible for some funds to be recovered by sales of selected products derived from the high technology activity. Examples of this in remote sensing are the software analysis package being marketed by a New Zealand software company, and the eight-channel radiometer.

6.2 Suggestions for expanded Commonwealth co-operation

The following suggestions are put forward in response to the questions raised in the original request from the Commonwealth Science Council, and in the knowledge of the situation described in the foregoing paragraphs.

6.2.1 Specific foci of relevance to expanded Commonwealth co-operation

(1) Data availability

The ready availability of remotely sensed data seems to be the key to progress and practice of the science. One solution for the Commonwealth as a whole may be a Commonwealth remote sensing satellite, with sensors of sufficiently high spatial and spectral resolution to satisfy the needs of all participating countries. Clearly, this could be an expensive option, and the method of funding would need to be scaled to avoid prohibitively high costs to small countries.

Another problem would be the reception of data from the Commonwealth satellite in remote areas such as the Pacific Islands. This might be overcome by preparing one or more transportable receiving stations which could be sited in different locations at different times. Use of a ship as a receiving platform and data processing centre could be considered.

A more modest solution would be the introduction of a remote sensing aircraft with high flying capabilities, which could be moved to different locations, and which could also contain an on-board processing system. Commercial versions of this concept already exist, and, again, it is the high operating costs which tend to inhibit its use, especially in small remote regions.

In the long term, the satellite option may be the preferred solution.

(2) Project evaluation

In many of the Pacific Islands, expertise in remote sensing is non-existent. The utility of these techniques applied to the solution of local problems is largely unrecognised. If remote sensing scientists could be temporarily seconded to selected regions, it would be possible to evaluate the type of problems which may be assisted by satellite or aircraft surveys. Some of these problems are already known, such as the need to map reefs and the relative positions of widely scattered islands.

Sufficient Landsat imagery exists already for some demonstration projects to be completed. The Peacesat geosynchronous satellite has been used for voice link meetings between scientists in the Islands and New Zealand. The discussions have covered topics such as the need to detect near-surface water, and to monitor the vigour of crops on the sparse soils. A programme of project evaluation, combined with selected demonstration projects, would help to establish the need for routine satellite or aircraft coverage.

(3) Scientific co-operation

In New Zealand, many applications projects would benefit from international co-operation, principally from exchanges between scientists. A far from exhaustive list of subjects of especial interest would include the following:

In co-operation with staff of the PEL remote sensing section:

Ground studies of reflectance and emission spectra in extended regions of the spectrum, including microwaves;
Investigations into the theory and practice of processing and interpretation of synthetic aperture radar images;

Studies associated with the computer processing of images from a geographical data base, into resource maps;
Design of image processing hardware and software;
Instrument design, including ground radiometry, spectrometry and solid state imaging systems.

In co-operation with other government departments and universities:

Correlation of sea surface temperature with remotely sensed thermal band data;
Mapping of sea surface chlorophyll;
Detection and mapping of soil moisture;
Correlation of topographical features seen from satellite images with mineralisation;
Detection and mapping of eroded and revegetating areas;
Estimation of timber volume in forests from synthetic aperture radar imagery.

(4) Co-operation in Space technology

Suggestions have been made that New Zealand should apply for associate membership of the European Space Agency. This would greatly enhance our involvement in the high technology area, with two major benefits. First, participation in the formulation and analysis of scientific experiments in Space would become possible. Second, design and production of some Space hardware, software and associated equipment in this country could become established.

The support of the Commonwealth Science Council in this endeavour, if deemed appropriate, may be a critical factor. In any case, the participation of New Zealand scientists in a Commonwealth initiative to build a remote sensing satellite would be a spur to the development of a technology base in this country.

6.2.2 Time frames

The short term (2 to 4 years) time frame is most applicable to the scientific exchanges listed in 6.2.1 (3). Periods of study of between one and two years will be sufficient to yield significant results in most cases.

Project evaluation and demonstration in the Pacific Islands could be a longer term (5 to 10 years) proposition, although a shorter initial study may be appropriate.

The establishment of a data source, either satellite or aircraft, is likely to be a longer term objective.

New Zealand involvement in Space technology is already in the embryo stages, with the development of image processing software and the eight-channel radiometer. We can foresee a steady growth over the next ten years.

6.2.3 Appropriate modalities of co-operation

These have already been outlined in the previous section.

6.2.4 Potential benefits for participating countries

The benefits to the smaller islands of the Pacific would result from the increased ability to monitor events in their economic zones, and hence improve their productivity.

The benefits to New Zealand would be to keep abreast of progress in a fast moving science, and possibly to ensure the continued availability of remote sensing data. In addition, the spur to the small high technology industries would be considerable.

The benefits to the other participating countries in the Commonwealth would be the opportunity to conduct investigations in a region of the world for which relatively little data has previously been available. Also, it offers a Southern base for studies requiring synoptic data from both hemispheres.

6.2.5 Infrastructural capacity of participating countries

In New Zealand, each co-operative program would be linked to a research laboratory, which might be one of the remote sensing sections in DSIR or Ministry of Works and Development, or to a user agency, such as the Ministry of Agriculture and Fisheries or the Forest Service. In each case, a Project Leader would be appointed, with the power to liaise directly with counterparts in the co-operating countries. It would be expected that the facilities of the laboratory would be made available as required. The same type of structure would exist for remote sensing groups in Universities.

In the larger Pacific Islands, similar arrangements would be made with appropriate Departments or Universities, while co-operative agreements in the smaller islands would be made at government level.

In the case of large projects such as the Commonwealth remote sensing satellite, the high level of funding required would need government approval.

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Commonwealth Science Council Paper

REMOTE SENSING - THE AUSTRALIAN PERSPECTIVE

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BACKGROUND

Australia is a vast continent with a relatively small population. It thus needed to develop technology for managing its resources, and was one of the early pioneers of remote sensing. With a vigorous use of aerial photography Australians developed expertise in interpreting what they saw from high up above the land surface.

The opportunities offered by satellites to provide a new, remote sensing perspective of Australia were therefore rapidly recognised and utilised. It became possible to obtain information that could not be afforded by using the older technologies. For the first time, ephemeral events such as floods and fires could be studied in detail. Damage caused by nature and man could be assessed on a month to month basis.

Australia has always taken a strictly user-oriented approach to remote sensing. Groups of specialists in various fields worked on the application of the new technology in their particular area of interest. Thus the new technology was integrated with the older technologies and the user's needs, in a highly efficient manner.

This means that Australia understands user's needs in relation to remote sensing, in tropical, arid and temperate terrains. Its experience in developing mineral and agricultural resources, and applying remote sensing technology in this development, is particularly appropriate for neighbouring countries in the Asian-Pacific region.

Australia's remote sensing capability rests primarily with its research groups and their resources, as well as their expertise in interpretation - but it also offers equipment, software, training facilities, and the use of specialised equipment and specialist personnel.

These resources exist in the Universities, in government, and in private industry. In particular, there are now a number of contracting companies that specialise in the provision of remote sensing services, and interpretation.

Current use of satellites

Australia has expertise in interpreting data from a range of satellite data, including Landsat, advanced very high resolution radiometer (AVHRR), heat capacity mapping mission (HCMM), etc. The data have been used in:

- crop forecasting, including rice and wheat
- tracking sandblast through wheat
- rangeland management
- monitoring land clearing and revegetation after fire
- mapping salt-affected land
- monitoring inland waterways
- mapping the extent of natural disasters such as flood, drought and fire
- analysis of ocean food systems for fisheries management
- mapping ocean currents for fisheries and shipping
- mapping irrigated land areas
- assessment of actual and potential land use
- exploration for oil and minerals
- detection of illegal crops
- detection of volcanic ash for aircraft safety
- mapping (e.g. recent discovery of the Navigator's Passage through the Great Barrier Reef)
- map revision (e.g. 1:250 000 scale mapping in Northern Australia)
- identification of the species of coral in reefs
- locating the position of buoys
- meteorology
- urban monitoring

For example, Landsat data are being used by the South Australian Department of the Environment to monitor the State's resources, and in particular to assist in the more effective management of the arid zone.

Areas irrigated for rice production are being monitored to provide information to predict the water requirements throughout the whole season, to improve estimates of rice production for the rice mills and to ensure that areas are not used too regularly, with a consequent rise in the water table and increasing salinity.

NOAA data have been used to locate volcanic dust clouds to assist in the diversion of aircraft around them.

Landsat data are widely used throughout the Australian mining industry, as an indispensible data source in exploration and mine planning.

Aircraft scanners

Remote sensing groups around Australia are now applying the expertise and technology gained in their use of satellite data to aircraft applications. This is generating much improved resolution, and will lead to a significant revolution in the usefulness of remote sensing in its many applications.

The scanners flown on aircraft have been used in:

- hydrology
- forest fire fighting
- water temperature monitoring (power stations)
- frost mapping for agriculture
- geological and mineralogical mapping
- monitoring ocean depth (with lasers)

For example, an airborne scanner operating in the far infrared (10 um) was used during the devastating fire storms of February 1983. It was able to map the location of the fire front at a time when smoke made visual location totally impossible.

A 2.2 μm spectrometer has shown the considerable potential for scanners operating at these wavelengths to be able to map, in accurate detail, the geology and mineralogy even in the presence of substantial vegetation and a thick weathered zone.

Image analysis

The Australian experience stresses the need for powerful interpretation techniques that extract and display the maximum information content of remote-sensing data, as well as allowing the simultaneous analysis of other relevant data sources. The need for these techniques has led to the development of numerical methods of processing and analysing the remote sensing data, and other data types,

including magnetics, gravity, radiometrics, geochemistry, and land ownership in image analysis.

The development of geographic information systems permits integration of several data sets to produce assessments of the extent to which sandblast is affected by slope, by soil type, by property. This type of analysis is proving invaluable to resource managers.

As an example, aircraft-borne radiometers simultaneously measure the radioactive radiations from potassium, uranium and thorium. By using these data as the three inputs to a conventional Landsat display system, an image is produced which offers a great deal of geological information. Such image display and analysis provides a very powerful extension of conventional remote sensing. Magnetics, gravity and other parameters are displayed in a similar fashion.

Aerial photography

Some of the image analysis techniques used so successfully with satellite and aircraft scanner data are being applied usefully to aerial photography.

For example, density slicing and false colour printing has been used in horticultural census. Horticultural plantings are monitored using images depicting annual changes in those plantings. Density slicing allows trees and vines to be distinguished from the rest of the image and an image taken in year 1 printed as magenta. In year 2 the image of the same area is printed in green. Changes appear as magenta (deletions) or green (additions). This technique has enabled horticultural surveys to be completed more quickly and more accurately.

Equipment manufacture

In response to developments in interpretation and initiatives in image analysis, a range of equipment has been produced, and in some cases marketed, including:

- image analysis equipment
- scanner systems
- filters
- software
- satellite tracking and receiving system (NOAA)
- field spectroradiometer
- laser film recorder

For example, software has been developed to reduce the noise in satellite imagery through a Fourier transformation technique. A microprocessor-based image analysis system, with a 512 x 512 colour display, is marketed by an Australian company. Highly accurate interference filters are being manufactured for airborne scanners, while a 15 channel scanner system has been developed for commercial use.

Image analysis software has been developed to process, transform and analyse high-resolution spectral data acquired from either airborne or ground-based platforms. This software has been extensively used in analysing rock and soil spectra for geological and mineralogical applications, and wll be utilised in agriculture to understand better the relationship between reflectance and physical status of different vegetative communities.

Training

Courses in remote sensing are being run at the University of New South Wales, Sydney, the Australian Mineral Foundation, Adelaide, and other tertiary institutions. Also, over the last 10 years, government laboratories have assisted industry in gaining expertise in image analysis. Landsat Conferences were held in 1979 and 1981 (and a third will be held in 1984), at which Australian remote-sensing groups exchanged information about the application of the technology in their particular area of interest.

Access to equipment/personnel

Australia has a bank of specialised equipment, as well as the people with skills in operating this equipment and interpreting the data generated. This equipment is distributed among specialist remote sensing groups. Each group has an area of expertise and, being application-oriented, is able to communicate readily with users relatively new to remote sensing.

COMMONWEALTH COLLABORATION

Australian laboratories have had substantial connections with a number of Commonwealth countries. These have included

- joint Landsat research with Papua-New Guinea
- a number of co-operative ventures with New Zealand
- extensive collaboration with Canada involving research into the use of aircraft scanners; spacecraft radar; and Landsat analysis.

FUTURE COLLABORATION WITHIN THE COMMONWEALTH

Foci The authors perceive that remote sensing will follow two, parallel, and complementary paths that will be based upon

(1) satellite imagery, thereby providing the ability to monitor ephemeral phenomena, within a sufficiently short time to permit the exercise of management options.

(2) aircraft imagery, that will provide high spatial, or spectral resolution, and which will be specifically "tuned" for specific uses.

The authors propose that the second path offers substantial avenues for Commonwealth collaboration. Thus they envisage

(a) Collaborative use of specialised aircraft scanners in the development of remote sensing techniques for specific purposes, and tailored to specific environments. It is envisaged that such collaboration might consist of one country supplying the scanner; the other the aircraft support and ground truth. In this manner, the skill levels of all the collaborators would be increased.

(b) Collaborative development of suites of narrow bandwidth filters that are optimally matched to specific problems.

(c) Collaborative development of data analyses, formatting, synthesis and storage techniques with special emphasis on small microprocessor based systems.

(d) The extension of technical and user skills through residential workshops, and other training schemes.

Time frame The above foci have the great advantage that substantial and relevant research can be achieved in short-lived, intensive field programs. The subsequent analysis phases would lead to enhanced interactions, and substantial technological spin-off.

Thus such collaborative ventures would consist of

- a ten month planning phase
- a two month experimental phase
- a one year analysis, and operational definition phase.

It is anticipated, further, that such bilateral programs could be arranged to utilise the same scanners, etc, in several countries in sequence. This would provide the Commonwealth countries with state-of-the-art equipment, at lower costs to all participants.

It is predicted that the collaborative program outlined above would have an overall liftetime of 10 years, although each individual project would only last 2 years.

BENEFITS

These are several

(1) the provision of remote sensing techniques optimised to the specific needs of the Commonwealth countries.

(2) provision of training that will increase each country's ability to analyse and utilise satellite remote sensing data

(3) immediate economic benefits through the utilization of remote sensing in land use planning; the management of agriculture, forestry and fishing; and in mineral exploration.

FACILITIES AVAILABLE

The necessary facilities, such as those outlined in the overview of the Australian scene, are available in a number of Commonwealth countries. Many others have the human skills to provide the ground truth, and the professionals required for planning and analysis. Together, the Commonwealth countries would be able to assist each other to a very considerable degree.

MICROBIOLOGICAL ASPECTS OF GENETIC ENGINEERING AND BIOTECHNOLOGY

Professor C H R Atkinson

This summary includes comments submitted by Professor A. Atkinson, Director, Microbial Technology Laboratory, PHLS Centre for Applied Microbiology and Research Salisbury, U.K.

In recent years microbiological processes have been used in biotechnology and genetic engineering and have shown that they could contribute to filling some of the most fundamental needs of human kind. For instance :

- World health has been improved through the discovery of the microbial causes of most human, animal, and plant diseases, leading to the development of vaccines, antibiotics, and chemical agents to combat many of these diseases.

- Foods have been improved in quality and protected from spoilage to enable wide distribution and storage against times of need.

- Sewage treatment methods have been developed to break the chain of disease transfer through waterborne pathogens. Microorganisms also enhance the water quality of rivers and lakes by degrading naturally occuring organic matter.

- Farming Practices have been improved through recognizing and capitalizing on the role of soil microorganisms; microbes have been used to break down nonedible crop residues for reuse by new crops. Nitrogen-fixing microorganisms have been used to inoculate legumes.

- Microbial fermentation processes have provided foods, beverages, medicines, and chemicals for human use.
  (A detailed list of the application of microbial processes to products used by industry is given in Appendix (i)

Microbes, as organized systems of enzymes, can often perform these functions more efficiently than purely chemical processes, and current environmental and economic constraints make the potential contribution of microbes increasingly attractive.

From these examples it is clear that microbes can be marshaled to aid in solving many important global problems including food shortages, resource recovery and reuse, energy shortages, and pollution. Microbiology is particularly suited to make important contributions to human needs in developing countries, yet it has received comparatively little attention.

In a study by Gyllenberg and Pietinen (1973) on the future of microbiology in developing countries it made a case for the allocation of funds to 'soft' applications - biological nitrogen fixation, the recycling of waste to help conserve the environment, traditional food fermentation, other food processing, and the control of microbiological vectors. It has sought to avoid 'hard' projects such as industrial build-up and the development of computer-controlled technology.

Nearly every developing country now has plans or programmes to exploit biotechnology for national development. Although each country must set its own specific priorities, a survey of microbiological processes was carried out by NAS (NAS, 1979) which identified the following subject areas with potential for developing countries to merit research and development for future use, they are:

- Identification of potential substrates for microbiological processes
- Food and animal feed
- Soil microbes in plant health and nutrition
- Nitrogen fixation
- Microbial Insecticides

- Fuel and Energy
- Waste treatment and Utilization
- Cellulose conversion
- Antibiotics and Vaccines
- Techniques for producing pure cultures

Modalities include training, information, collaborative research, institution building.

The duration of research in any aspect of biotechnology is almost always long term.

Professor Atkinson has commented that the benefits perceived would depend entirely on the nature and scope of the collaborative programme undertaken, as also would the needs perceived.

Furthermore, Professor Atkinson argues strongly that it is impossible to divorce Microbiological aspects of Genetic Engineering and Biotechnology from other aspects of these subjects, and he considers that the Expert Group should consider scientific cooperation in Genetic Engineering and biotechnology for both higher organisms and microorganisms together.

Many international agencies are participating in biotechnology projects. (See Appendix (ii). (ii) Any CSC activities should therefore be based on a clear examination of the efforts of these agencies.

If CSC were interested to examine the prospects of a programme in biotechnology and genetic engineering Professor Atkinson recommends a group should be appointed to assess the facilities, resources, interests and capabilities of each Commonwealth Country. The group should then produce a list of viable areas of Scientific Cooperation in Biotechnology and Genetic Engineering based on which future CSC activities could be developed.

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IMPACT OF BIOTECHNOLOGY FOR DEVELOPING COUNTRIES OF THE COMMONWEALTH

B S Hartley

1. Definitions. Biotechnology has become a band-wagon and there is danger that the weight of those who seek to jump on may affect the speed and direction of the vehicle. The Spinks Report (1) in 1980 purposely chose a narrow definition designed to emphasise the application of recent breakthroughs in molecular biology to industrial processes. In the U.K. context at that time this narrow focus was appropriate, since relevant research in medicine and agriculture was already well supported. In the current Commonwealth survey it would be wise to adopt a broader definition, but not so broad as to include the whole of medical and agricultural science: otherwise mere reshuffling of existing resources may take the place of genuine new initiatives.

Hence I will use the term biotechnology to include practical applications of the dramatic advances in protein and nucleic acid chemistry, molecular genetics and recombinant DNA technology to relevant problems in medicine, agriculture and industry in developing countries of the Commonwealth. This is not intended to underrate the 'old biotechnology' which is quantitatively far more important in fields such as food technology, brewing and antibiotics production. Indeed I argue that biotechnology is the interdisciplinary area in which these new techniques of biochemistry interface with established technologies of microbiology, fermentation and biochemical engineering.

2. Is biotechnology relevant to developing countries? Obviously yes, but not necessarily in the same directions as in industrialised countries. There the immediate emphasis has been on new and expensive drugs or on large-scale and capital intensive projects, e.g. I.C.I.'s animal feed from methanol, high-fructose syrups to replace sucrose or new synthetic sweeteners such as Searle.s 'aspartame'. These threaten the economies of developing countries rather than assist them.

Some recent Western initiatives do have more relevance to the Commonwealth as a whole. A genetically engineered vaccine for hepatitis B will shortly be available, but its cost may be prohibitive for those countries that could use it most. This cost could plummet if a major world-wide immunisation programme were launched. But will that happen? Developing countries must themselves decide what proportion of their resources can be devoted to such advances in human health.

On the agricultural front, there will be greater consensus. Unilever's oil-palm cloning offers a route to strain improvement of plants that are difficult to propagate by conventional division or grafting. Longer term prospects of plant genetic engineering are also likely to gain votes: no one objects to making two ears of wheat grow where one grew before, even though the road to this goal may be long and costly.

But I believe that it is the industrial aspects of biotechnology that will prove most relevant to developing countries of the Commonwealth. Tropical countries are, or could be, the most effective producers of plant biomass. Fermentation substrates derived from such plants or plant wastes are the raw material for the new biotechnology. Western producers will probably continue to win with high-value products such as interferons or growth hormones, but certain developing countries could become the world's major producers of bulk chemicals from biomass. Indeed I will argue that ethanol from sugar cane might shortly challenge petrochemical ethanol in world markets.

Hence I am confident that developing countries cannot afford to be second or third in certain aspects of biotechnology. Processes designed for high value products from temperate crops of the U.S.A. and Europe will not prove easy to challenge or to licence. But the way is open to develop new products from indigenous crops of tropical countries, that will at worst provide considerable import substitution and at best offer important export potential.

3. Impacts on medicine. New drugs produced by genetic engineering such as interferons, insulin or growth hormones will have great impact on medicine, but will poor countries be able to afford them? Disabling diseases like malaria, tryponosomiasis and hepatitis are probably of higher priority for the Third World, and genetically engineered vaccines offer new hope here. If there were a major world-wide initiative to develop and use these vaccines to attack these diseases, the research effort would be greatly stimulated. As things are it would be a major risk for any pharmaceutical company to develop a major programme for a malaria vaccine, especially if the clinical trials prove as costly as might be predicted. Hence this is a target to which a multinational and publicly-sponsored programme might aim: an effective contribution by scientists and clinicians within developing countries would not come amiss.

Epidemiology and diagnostic medicine are about to be revolutionised by biotechnology. There will be a natural belief in Third World countries that they cannot afford such sophisticated medical aids, but I wonder if this is really cost-effective? Appplication of the right vaccine to the right patient at the right time is certainly good value for money. Can developing countries afford not to train staff and provide resources in these areas?

4. Impacts on agriculture. Here I would expect considerable consensus from developing members of the Commonwealth since a considerable proportion of their scientific manpower is already in this field. I caution that although the benefits are undoubtedly large in the long term, they may be slower to accumulate and individually less dramatic than is popularly envisaged. Consider, for example, the prospect of cloning genes for nitrogen fixation into major crop plants. The task of constructing vectors that will allow effective expression within

the host cell is daunting. This task will be useless unless a stable plant line can be regenerated from the transformed cell. And sceptics will argue that growth of that plant would be diminished by diversion of the photosynthetic energy to use in nitrogen fixation: why not let microorganisms do the job by feeding on cellulosic wastes that are ploughed back into the soil?

Yet I strongly endorse a Commonwealth programme designed to build up a cadre of young scientists with skills in the art of plant genetic engineering. The target would be a greater understanding of the genetics and biochemistry of major tropical crop-plants e.g. rice and sugar cane. One would not look for practical results in the short or even medium term: the quality of the scientific questions asked and the cost-effectiveness in which they were answered would be the key criteria. The medium term strategy would be to enhance considerably our abysmally inadequate knowledge of the biochemistry and genetics of plants that feed so many poor Commonwealth citizens. Long-term aspirations like breeding for increased grain yield, protein content, disease resistance and climatic or soil tolerance would build on this basic study.

5. Animal husbandry. Europe, North America and Australasia have raised meat production to high levels of efficiency. Animal diseases are now worth curing and animal growth hormones produced by genetic engineering promise increases in meat yield with no increase in food intake. Considering the low productivity and high mortality of animals in Third World countries, one would guess that these new techniques would be even more productive. However I doubt that large-scale elimination of animal disease by vaccination is an early probability in these countries: it is surely more important to tackle human disease first. This criticism may not apply to animal vaccines in the small island states of the Commonwealth, where a determined effort to wipe out certain animal diseases might pay dividends.

6. Industrial impacts. In the short term, bulk chemicals from sugar cane stands out as a target for a Commonwealth initiative in biotechnology. The big chemical and oil companies in Europe and North America are not interested in ethanol from biomass since current oil prices produce petrochemical ethanol more cheaply than current or predictable processes based on temperate crops. However Indian costs of ≲250/tonne of fermentation ethanol contrast favourably with European prices of ≲400/tonne for petrochemical ethanol since the huge Indian surplus of molasses minimises the substrate cost. This Indian price is also based on low-technology, and new processes in the pipeline such as my own 70°C ethanol fermentation based on a genetically manipulated Bacillus promise to reduce the cost to about ≲200/tonne. India already has an expanding chemical industry based on fermentation ethanol - the I.C.I. (India) polythene plant for example, and a variety of other bulk chemicals are in manufacture based on feedstocks derived from sugar cane.

The commercial prospects are even greater if new methods can be devised for producing bulk chemicals from lignocellulosic wastes such as cane bagasse and rice straw. Bagasse is currently burned inefficiently to fuel cane refineries and ethanol plants. The new processes for ethanol mentioned above combined with good energy management would require only half of the dry weight of the bagasse, leaving half for conversion at effectively zero substrate cost. On this basis microbial conversions become potentially economic for medium sized cane refineries and chemical hydrolysis by the ICI LiCl process would be attractive if an adequate volume of bagasse could be trucked cheaply to a central site. For island states, a ship-based conversion plant is an option. Hence research in this area is likely to be of mutual benefit to many Commonwealth countries. This same research should be readily adaptable to other lignocellulosic wastes such as rice-straw, palm husks etc.

On a longer term basis, research into lignin degradation should pay off, because the above processes would generate a mountain of lignin. There are recent breakthroughs in this field which suggest that a combination of enzyme degradation plus microbial transformation would yield useful aromatic chemicals.

Indeed microbial transformations of bulk chemicals into higher valued products such as drugs, pesticides or insectides could become a speciality of the developing countries. Western companies are wedded to large-scale chemical conversions that can often be circumvented by subtle microbiological steps.

7. What can CSC do to help? From what I have seen in India and in the literature sent to me, I am impressed by the efforts and potential in the field of biotechnology that are currently available in many Third World countries. However there is danger of duplication of effort and need for improved information transfer to avoid pitfalls and accelerate spread of good techniques. One simple initiative therefore would be to build up an information base readily accessible to scientists in Commonwealth countries. Ideally this should be by computer link to at least one centre in each major area and direct aid to establish this would be appropriate. Subsidiary links would be the responsibility of the host country. One should recognise that sensitive commercial information requires safeguards on dissemination.

Another important initiative would be transfer of key scientists. Training in advanced centres in the U.K., Canada and Australia should be expanded but there is also need for fellowships for secondment of staff between laboratories in the developing countries.

Equipment grants may be necessary in some locations but one would expect an appropriate matching commitment from ths host country.

Consumables expenses should be limited to supply of materials

available only through foreign exchange. Where staff transfers are made between developing countries, the host should agree to meet research expenses outside this limitation.

Research priorities should focus on collaborative projects of mutual benefit. An exception may be made when there is need to train young scientists in advanced technologies, where it is best that they should slot into an active current research project.

A peer-review system is essential to select and monitor projects. Direct intervention along the lines of the U.K. Biotechnology Directorate could be useful. One would wish to avoid major representation by beneficiaries on such a Directorate.

MICROELECTRONICS

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1. Introduction

The fields of microelectronics and information technology are ones in which there is great activity in all countries, ranging from massive Government programmes such as VHSIC (Very High Speed Integrated Circuits) in the USA, the Alvey programme on Information Technology in UK, the ESPRIT (European Strategic Programme of Research and Development on Information Technology) programme in the European Community to individual efforts in Universities. The major problem in recommending topics suitable for promotion by the Commonwealth Science Council is to avoid embarking on research where it is probable that results will be achieved much more rapidly from the well established research groups. A related problem arises from the very large costs of equipment needed to attack many of the possible research projects in these fields. In what follows, these problems have been kept in mind and an attempt has been made to identify possible research lines which have some feature which can be of special interest to one or more countries of the Commonwealth and which can benefit, as much as possible and as quickly as possible from the advances made by teams outside the Commonwealth. Information on the existing programmes mentioned above is readily available. The UK Alvey Committee report provides a convenient reference to use as a pointer to the possibilities which should be considered.

Three topics - the design of VLSI (Very Large Scale Integrated) circuits, IKBS (Intelligent Knowledge-Based Systems) and Robotics - are identified as areas in which it should be possible to frame Commonwealth programmes. Indeed it might be argued that without programmes in these areas the gap between developing and developed countries will become even wider. The intention is to seek programmes which depend on the technology already available or likely to be available very shortly and which will be more likely to be successful if teams of collaborators can be set up.

2. VLSI Circuits

The fabrication of semiconductor devices, especially VLSI (Very Large Scale Integrated) circuits, is often described as an enabling technology, since it is the products of this technology - the silicon chips - which provide the building blocks for the many and varied systems which come within the scope of Information Technology. VLSI fabrication is a very expensive, and now highly sophisticated business. It is very unlikely that any small group working

independently of the large manufacturing organisations can compete successfully in research on the technology itself. But, a different situation arises in respect of the products of the technology and the design processes associated with individual products. The range of products is very wide and a very broad distinction can be drawn between the industry-standard products, such as memory chips, where very large design investments are recovered by very large sales and the custom product, tailored to meet the needs of an individual customer and available to that customer at modest prices even for small production runs (i.e. less than 10,000 devices). The growth area for micro-electronics arises from the almost unlimited opportunities for manufacturers of many existing products to add "intelligence" to these products by a combination of industry-standard devices plus one or two custom-designed devices to give their final product its own individual capability. The ability to design these custom devices is essential for today's low-technology industries in areas such as consumer goods, instrumentation, etc. to remain competitive, and this should be seen as one topic for a Commonwealth Science Council programme.

VLSI design takes place on three recognisably different levels:

(i) major programmes, typically up to 200 man-years for a single device, for industry standard products,

(ii) full custom design in which all steps in the fabrication from the initial silicon wafer to the final device are designed to meet the customer's requirement,

(iii) the use of "uncommitted logic arrays", i.e. arrays of standard logic cells, fabricated in bulk with the final one or two processing steps customised to meet individual requirements.

The programme proposed for CSC support should be directed towards ensuring the widest access to the third, and simplest, design level and access by some countries to the second level. What would such a programme entail? At present, most ULA manufacturers offer services and packages to customers, providing differing degrees of customer participation in the design process. Since design at this level must be based on a particular ULA type, a link with a manufacturer is essential. The major resource needed to complete the design is a modest level of computer power (specially designed work stations are likely to become available). The design process itself may be relatively straight-forward, particularly if the ULA manufacturer's software is used. But, even so, the availability of such a facility opens up the way for innovative circuitry which would otherwise be difficult to realise in discrete form.

Further, although there are available fully-tested design software packages, there is scope for improving these. The interface between the customer for the circuit and the circuit designer is one in which developments such as improved specification languages are being pursued. A related problem, where again research is continuing, is in the development of means to provide effective tests of circuit performance, a task which becomes steadily more difficult as the complexity of circuits increases.

Entering the VLSI design field thus offers access to circuits needed to allow research in fields such as communication to move ahead and also opportunities to become engaged in research into improved design and test procedures.

3. Intelligent Knowledge-Based Systems

IKBS, or expert systems, as they are sometimes called are one of the results of the extensive work in recent decades on the wider field of artificial intelligence. Examples of such systems operating in subject areas such as medicine already exist and the computer software on which they depend can be adapted to cover other areas. There are many opportunities for IKBS to be used where human experts are in short supply but where the information which they possess should be disseminated as widely as possible. A research programme aimed at developing expert systems for use on topics indigenous to Commonwealth countries would require teams of workers embracing both software experience and experience of the particular field in which expertise was being applied.

4. Robotics

The availability of standard robots in a wide range of sizes and with different operating characteristics allows applications research to proceed. Programmes in UK Universities cover applications of robots to a very wide range of industries and similar programmes could be set up in Commonwealth countries. These programmes require investigations in several areas - the software used to control the robot, the design and construction of special tools and the design and construction of sensing devices. Such sensing devices are likely to be more effective when appropriate levels of signal processing are used. Such signal processing requirement can be achieved by using custom-designed chips as discussed in para 2 above.

5. Overall Comments

The areas discussed above have several common features. In each case there is already available an extensive bas of existing technology and the aim of the suggested CSC programme is to allow Commonwealth countries to become familiar

with and thus to be able to exploit such technology. In each programme, there is a need to have as much collaboration as possible: in VLSI, there should be agreement on which ULA(s) are to be preferred, in IKBS, the use of common software packages is likely to avoid unnecessary duplication of effort and in Robotics, the research results can be shared. Two questions arise: how should such programmes be started, and how should effective collaboration be maintained? One possible answer to the first question is to select a centre in the Commonwealth where work is already in progress and to second staff from other countries to this Centre for at least one year during which these staff build up their own expertise and agree a joint programme. If this were done, such a group could then decide how to proceed, whether for example to appoint a co-ordinator or whether to rely on regular conferences.

COMPUTER AIDED DESIGN & DRAUGHTING

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A) INTRODUCTION

Computer Aided Design & Draughting or more explicitly, Computer Graphics Aided Design & Draughting(CADD) involves the use of computer technology for draughting or designing:

- a product, such as aircraft, VLSI IC board, shoes, garments;
- a process, such as a plotting or mapping technique, or an automated manufacturing process; or
- a plant, such as a nuclear power plant, a military radar plant, or an architectural plan.

Depending on its degree of sophistication, a CADD system can be used to generate technical/engineering drawings (architectural, mechanical, or electrical) - modular or merged - perspective views, artists impressions or 3-D modelling of engineering assemblies.

In CADD, processes of generating geometric data and engineering drawings of parts, components, products or plants are automated, to within the designer's man-machine interactiveness to editing and modifying of metrical and topological attributes. CADD technology, hardly much known ten years ago, is a keypiece in the microelectronics applications revolution that will probably allow development of the automated 'factory of the future', through Computer-Aided Manufacture, (CAM). Inherent versatility, product lead time, and product materials optimization are some of the basic characteristic features that place CADD well ahead of traditional engineering methods of draughting and design.

B) HARDWARE CHARACTERISTICS

Four sets of Hardware Components are essential for the realization of CADD systems, namely:

(a) The CAD Processor Unit

This is the CADD system's CPU and functionally comprises the three basic parts which essentially constitute the central processing unit of a computer, namely:

- the Controller, which carries out the function of selecting and retreaving of instructions from storage, interpreting them and initiating the required operations;
- the Arithmetic Unit, which performs arithmetic operations on relevant operands. May also be used to perform arithmetic shifts, logical shifts and other logical operations on data; and
- Core Storage, which stores programmes and data for immediate use.

(b) Work Station

This constitutes the CADD graphics systems equivalent of all basic draughting paraphernaliae and comprises:

(i) the VDU, which is the graphics system's equivalent of the draughting board. Facilitates output of data in the form of a graphics screen display and enables iterative interactiveness to amending of design.

(ii) Draughting Keyboard and the Light Pen, which are the graphics systems equivalents for the conventional tools (drawing instruments, and templates) required for general traditional draughting tasks:

- The Keyboard facilitates an inputing of data;

- The Light Pen allows communication between designer and the CADD terminal (VDU). The Light Pen is a pen-like high-speed photosensitive device which when held against the face of the VDU screen, the point of contact with screen can be determined by the computer. Geometrical characteristics of figures (points, lines, shapes, patterns and views) can be automatically displayed or selections can be made from a Display Menu. A CADD Display Menu generally consists of common commands relating to operations on points, lines, shapes, patterns or views and on other draughting functions.

(c) Plotting Device or Paper Tape

Plotting Device or Paper Tape allows presentation of final design in the form of drawings (for paper-based systems) or in the form of numerical coordinates (for automated systems) respectively. A paper tape is a storage medium consisting of a long strip of paper into which holes are punched in a row across the width of the tape, different patterns of holes signifying different characters.

(d) Add-on-Memory

This is basically a diskette (also: flippy or floppy disk) to supplement onto the core-memory of the CADD processor Unit. Drawings saved on a diskette can be restored to disk working storage for editting or plotting purposes at any time.

C) SOFTWARE REQUIREMENTS

Essentially, two different elements of software are required for CADD systems:

(a) Basic Graphics Software

This enables a CADD system:

- to construct basic geometrical characteristics of figures, namely: points, lines, shapes, patterns and views;

- to perform certain geometrical transformations like translations, mirror reflections, enlargements, rotations, etc; and

- to carry out certain metrical operations on lines, shapes, orientations, etc, such as length and angle measurements.

(b) Applications Software

The use of CADD systems for design will normally require programmes and packages designed to satisfy specific applications, namely: mechanical, architectural, electrical/electronic, etc. These constitute the CADD system's Applications Software. Three basic levels or 'echelons' of CADD applications software may be identified:

- 'Echelon I' Programmes - these are fairly standard programmes, purpose-built or incorporated as applications packages;

- 'Echelon II' Programmes - these are applications software that are currently under development, such as those relating to 3-D modelling;

- 'Echelon III' Programmes - these pertain to applications software that are heavy users of data, such as those required in engineering stress analysis designs. Echelon III programmes would normally require powerful mainframes for their execution.

D) NATURE OF CAD SYSTEMS

The following characteristics may be delineated, namely -

- CAD systems enable design data base to be reduced to the basic binary building blocks which are the fundamentals of all electronic systems;

- graphical capability through electronification of design in CADD systems gives the designer a man-machine or human-computer communication through the medium of graphics. Moreover, CADD gives the designer a high degree of capability to iterative interactiveness in 'real time' with the model under design;

It is well to note, however, that conventional CADD systems automate the process of design generation (geometric data and engineering drawings) of parts, but they do not determine whether these parts meet structural or other physical performance requirements. Ordinarily thus, Design Generation and Design Analysis involve different computer systems -

(i) Design Generation: here the "Designer" uses one computer system (a CADD system) to produce engineering drawings of a given part or parts of a structure, etc;

(ii) Design Analysis: here the "Evaluator" or "Analyst" creates a physico-mathematical model with which to test the design on another computer system (not necessarily part of a conventional CADD system). Design Optimisation would thus involve a separate interaction between Designer and Evaluator followed by appropriate metrical adjustments in a CADD system. For engineering purpose it might be expedient to have an 'Optimal Shape Generation' system, capable of integrating the processes from Design Generation, Design Analysis through Design Optimisation.

E) TYPE OF CADD SYSTEMS

Criteria for choice of CADD systems or individual hardware or software components thereof are contingent upon the user's sophistication of design requirement. Subsequently, three types of CADD systems are available :

(a) 'Microprocessor-Based Systems' (MPBS), with basic draughting software and dedicated to only a few applications programmes with very limited analytical capability. These are normally small, not very powerful and are basically suitable as pure draughting aids, a "draughtman's graphic processor".

(b) 'Minicomputer-Based Systems' (MCBS), dedicated to graphics use and accepting a variety of different applications programmes, with limited liability to analytical capability, however. These are more flexible, more powerful and form the basic processing capability for all 'turnkey' systems, with ability -

- to 'understand' a large number of applications, programmes as well as to function as a draughting tool; and

- to drive between a large number of terminals depending upon the particular supplier's software and use made by the user.

(c) 'Mainframe-Based Systems'(MFBS), which are partly used for graphics and partly for information processing and analytical tasks. These are powerful enough to undertake more taxing requirements of software applications, to process data bases and to allow multi-user capability.

F) Acculturation of CADD Technology

The earliest CADD applications programmes were developed for the electronics sector and now almost all IC industries from the West for VLSI manufacture use CADD as part of their standarized design procedures. The diffusion of CADD into the printed circuit electronics industry has been, nevertheless much more limited. Reasons for this disparity pertain largely to:

- choice of technique; and

- the fact that CADD technology has only recently become available at cost-competitive levels to justify widescale use.

A leading sector to date for CADD seems to be in the field of mechanical engineering. The absolute size of the mechanical engineering make it the largest potential user of CADD as well. That the diffusion of CADD technology (Kaplinsky, 1982) for the United States (the most advanced user of all countries with possible exception to Japan) stood at 'less than 5 per cent' in 1980 is suggestive of a quasi-static rate of technological process acculturation of CADD industry. Future areas of focus seems to point to architecture, civil engineering and structural engineering sector.

In the less developed countries (LDCs), focus in CADD has been predominantly in mapping, generally in relation to oilfields. A general interest from LDCs has been reported especially from China, Hong Kong, Taiwan and Singapore covered with the purchase of the state of the art technology, but without any specific knowledge of the uses of CADD, or even of its nature or cost. Indigenous development of CADD systems within LDCs seems to pertain only to that from India's Tata Institute of Fundamental Research.

G) Possible Foci on Locus of CADD Diffusion in Commonwealth Countries

Indigenous Commonwealth CADD capability seems limited to date to India and even then its impact is only primordial. A perspective for possible Commonwealth foci can only be surmised at least in relation to most likely areas of diffusion:

(a) CADD as a Draughting Tool

Use of CADD as a draughting tool is expected to diffuse more easily in areas that involve reduction of draughting costs by savings in draughting skills:

(i) Draughting of agricultural implements, leather products, textile products, apparel products, wood products, and food products.
This would conform to the predominantly agricultural agrarian settings of the majority of Commonwealth member countries.

(ii) Draughting of electrical equipment, office equipment and domestic plastics equipment. This would add technological sophistication to an existing industrial base.

(b) CADD as a Design Tool

It would appear expedient here to relate CADD to the enhancing of electronics capability among member countries:

(i) In VLSI chips where CADD is imperative for any meaningful development of the microelectronics technology;

(ii) In ULA chips, a new and very important potential trend in the electronics sector which unlike existing chips, the final logic is user-specific rather than manufacturer-specific. Apparently the subsequent connection of 'uncommited' logic gates (for user-specificity) cannot be done without the use of a very sophisticated CADD facility.

H). Entry Impasse to CADD

Investment in CADD is a relatively profitable activity both in relation to an industro-economic development and to a techno-scientific promotion of endogenous capability. There, however, exists an element of impasse to entry in the CADD industry: it is the question of technology.

It is probably a platitude to date that technology is a "free" or "public" good and that it is not used up in consumption and is available for multiple and indefinite use. A corollary to this is that contingent upon availability of some mechanism to protect proprietary rights over this apparently "free resource", there will be no incentive, under industro-economic systems for the generation of new technology:

(a) For embodied technology (such as equipment, machinery, etc) a mechanism is provided, at least partially, by the patent system which gives exclusive rights for exploitation to the owner of the patent or its licencees.

(b) For non-embodied technology (such as CADD applications software) only copyrights can be provided, which is easily circumventable. Yet for CADD industry to flourish, there must by necessity exist a process of effective appropriation.

The existence of an impasse such as the above does not and need not constitute a barrier to any modalities for Commonwealth cooperation in efforts to gain capability in CADD.

I) Modality of Cooperation

(a) Training of scientists, technologists, engineers and designers on regional basis, on fundamentals of CADD applications software development. CADD software writers may, however, be divided into three groups:

- those committed to the development of operating systems;
- those concerned with update and maintenance of applications programmes;
- those involved in the developing of user-specific programmes for local-flavour applications.

(b) Exchange Programmes involving software writers between developed and developing member countries of the Commonwealth.

(c) Information Exchange for the education of CADD software engineers and scientists.

A modest start could involve centres of high learning and industrial research.

J) Time Frames Perceived

Timeframes involved would probably be contingent to a number of factors including:

- extent to which a country's industrial base is sophisticated to warrant introduction of CADD;
- extent of diffusion, into various sectors of a country, of the microelectronic technology; and
- perceived impact of introduction of CADD into a country's industrial sector in relation to concomitant re-distribution of labour.

In the short term, however, initiatives at CADD could start with use of MPBS and MCBS at universities and research institutes. With some threshold growth in pertinent features of the CADD know-how, long-term ventures could then envisage to introduce MFBS for industrial use.

K) Benefits Perceived

(a) Benefits Related to Impact on Product

These include:

(i) CADD as an essential tool

(ii) CADD as an optimising tool

(iii) CADD as a product lead time tool.

(b) Benefits Related to Information Technology

Extent of information required by most CADD users are generally enormous (parts listings, 'bills' or materials, 'orderings', etc). CADD could give impetus to development of IT pertinent to inter-communication, integration of data processing, analysis and systematization of inventories, etc.

(c) Benefits Related to Production

In the manufacturing sector CADD benefits include:

Materials Saving - due to optimization of design and nesting (programmes developed to cut shapes out of a sheet of material.

Prototype Elimination - for more accurate CADD drawings reduce and possibly eliminate the need for and costs of manufacturing prototypes.

Whatever the variety, benefits accruing from CADD can be classified into three major areas:

(a) CADD as a Draughting Tool, relating to the choice of technique;

(b) CADD as a Design Tool, relating to both the choice of technique and its influence on the products, and

(c) CADD as 'Downstream' Benefit Mechanism, relating to CADD as a key to systems gains.

L) Needs Perceived

- Capital equipment for viable CADD systems;

- Professional expertise for local training in various aspects of CADD.

M) Practicability of CSC Finance

The establishment of viable infrastructures would require heavy outlay in terms of financial and specialized manpower resources. Collaboration with other organisations would be expedient. UNIDO, inter alia, could be approached on aspects pertinent to training and installation of CADD systems.

It is well to note, however, that introduction of CADD carries with it certain social implications:

- the introduction of CADD changes the nature of industry from a traditionally labour intensive activity into a capital - intensive one, thus impacting on countries with capital constraints, foreign exchange limiations and high levels of unemployment; and

- by virtue of its performance, CADD renders manual design techniques sub-optimal, thus demanding a trade-off from developing countries between technological efficiency and economic appropriateness.

A thorough cost-benefit analysis of all pertinent basic factors associated with a CADD system would be an expedient preamble for any country that intends to launch a Computer-Aided Design & Draughting (CADD) programme with an ultimate aim to Computer Aided Manufacturing (CAM).

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Computer Literacy Programme

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(a) Introduction

1. At its second meeting, the Expert Group noted the importance of microcomputers for schools and colleges in respect of both hardware and software development and as teaching aids, and considered it important in the short and long-term for young people to become familiar with microcomputers through a mass education and literacy programme in the Commonwealth. It felt that such a programme should consist of an introductory course, using the Open University approach, through distance education and video tape techniques. The Group requested Professor H S Tan to form a Committee to explore the possibilities of establishing a Commonwealth Computer Literacy Programme in consultation with the Open University, BBC Computing Unit, Pacific and Caribbean and other small states with distance education technology, and the British Council.

2. In order to facilitate the consideration of this concept of a Commonwealth Computer Literacy Programme further, information on the on-going activities of the Open University, BBC, British Council etc. have been secured and summarised in this paper, with some comments.

(b) Open University

3. Opportunities for people in industry, commerce and the public services to learn new skills and develop existing expertise are available through the Open University's Centre for Continuing Education at Milton Keynes. The University offers a variety of computing courses which enable students to study independently in their own time, or with groups of colleaques. There are no entry qualifications or selection procedures involved in taking any of these courses. The courses involve varying amounts of work which the student can pace to suit personal circumstances. The materials range from packages including ready-to-use micros to courses which give access to the University's Academic Computing Service, at levels varying from introductory to postgraduate. Each course, besides making available the relevant computer technology, includes texts, cassettes and study guides which integrate the materials.

4. Government finance is supporting the University's expansion of Continuing Education to help people update their working knowledge and skills. In addition to the programmes which are broadcast over radio and television, the Open University also offers short courses through self-contained packages which may comprise, for instance:

   - Course Text, Activity Booklet, Standard Telephones and Cables, Case Study, and Study Guide.

   - Video cassettes of television films on loan.

   - On line access to Open University Academic Computing Service and advice by phone.

5. There are wide ranges of such courses available from introductory to specialist courses for industry:

   - Data analysis for information system design.
   - Introduction to commercial data processing with COBOL.
   - Introduction to system analysis and design.
   - Microprocessors and product development course for industry.
   - Microprocessors and product design: a course for engineers.

(c) Microelectronics Education in Schools

6. The Microelectronics Education Programme was initiated in March 1981 and is currently due to end in March 1986. It is financed by the Department of Education and Science of England, Northern Ireland and Wales, and administered by the Council for Educational Technology. MEP has provided the content of the teacher training packages (funded by the Department of Trade and Industry) for the secondary and primary sectors, and has allocated funds for curriculum development materials for use in UK schools. Approximately 35 000 teachers have received training so far.

7. Also for use by children in the classroom, MEP has funded the development of a wordprocessing package called EDWORD to assist children gain confidence in creative writing, understand grammar and spell more effectively, and generally gain self esteem through using this package. A new programme of 'Microelectronics For All' has been launched this year. The modular form of the hardware package allows schools freedom to adopt and adapt the material to meet their own requirements. MEP philosophy encourages such freedom in the hope that feedback from teachers will help others involved in curriculum development to further create materials which will help the UK continue to lead in this area.

(d) BBC Computer Literacy Project

8. The aim of the BBC Computer Literacy Project launched in 1982 is to introduce interested adults and younger students to the world of computers and computing, and to provide the opportunity for viewers to learn through direct experience how to programme and use a microcomputer. The project is built around two ten-part television series: The Computer Programme and Making the Most of the Micros and includes a book, a linked microcomputer system complete with User Guide, a range of applications programmes, and associated courses in programming in BASIC, and other aspects of computing, provided by the National Extension College, in Cambridge.

9. The project forms part of a long-term commitment by BBC Education to public information in the broad field of microelectronics, which has included the three-part series 'The Silicon Factor', and the five-part series on applications of computers in business and industry,

'Managing the Micro' and some programmes on the implications of microelectronics for teachers, 'Micros in Education'. The series being broadcast this year concerns specific aspects of computing. "Computers in Control" gives an introduction to robotics, monitoring and control applications using the microcomputer. The Electronic Office is a series which explains and explores the revolution in office technology. In addition to these programmes, there is a television series 'Micro Club' and the radio series, 'The Chip Shop' both of which are magazine programmes for enthusiasts. The Computer Literacy Project is expected to continue in 1985.

(e) The NEC Courses

10. The National Extension College is providing a 30-hour introductory course in programme in BASIC in association with BBC project (with which it is software compatible). It is possible to follow the course as a home-based correspondence student, to use it as a flexi-study course with a combination of home-based work and work in a supporting college, or simply to buy the course book '30-Hour BASIC' and use it independently. The course is linked to a network of local colleges where individuals can have access to machines and tuition if they wish.

11. Three further NEC programming courses are available:

- The first covers more advanced BASIC including structured programming, programme style, graphics, problem solving, data vetting and error trapping, file handling and games. This will be a BBC/NEC co-publication and will also be available as an NEC correspondence course.

- The second is an introduction to 6502 assembly language programming covering: binary and Hex numbers, addition and subtraction, multiplication and division, branching, addressing modes, lists and tables, parameter passing techniques, VDU and operating system calls and programming style. This will be a BBC/NEC co-publication and will also be available as an NEC correspondence course.

- The third is on control applications of the BBC Micro and is designed for use with the control kit (available from later this year). The projects in the course include: traffic lights, an alarm clock, measuring the speed of a record player, reading bar codes, measuring temperature, fire detection, burglar detection, morse coder, applications for the handicapped and controlling a stepper motor.

(f) British Council

12. The British Council does not participate in the British Computer Literacy Projects. It however assists people from developing countries to receive training in Britain on computer technology through ODA support. In recent years, requests for such training has been considerable. British Council also conducted a course in Oman on commissioned basis.

(g) General Discussion

13. It is evident that, in Britain, considerable success has been achieved in enhancing computer literacy by the various efforts. The BBC Computer Literacy Project is only one of several initiatives. The BBC initiative alone involved building of a new computer (BBC micro), design of television programmes acceptable at many levels (schools, teachers, adults from different backgrounds), publication of back-up literature, and availability of home study pack. Over two hundred thousand BBC microcomputers have been sold to individuals, schools and businesses. Britain perhaps has the highest density of micros per head of population of any country in the world due primarily to the availability of cheap microcomputers, particularly those produced by Sinclair, and others. Britain also is believed to have the highest rate of computer literacy in the world resulting from the successful efforts by BBC, Open University, Government, and the educational institutions. Inspite of these successes, there is still a generation gap which will prevail in other countries. The young are ahead of the old; the world of computers is rapidly becoming the province of the child and the young adult. Its literal logic does not come easily to the mind-set of the middle aged who are nevertheless affected by the infusion of this new technology. Computer literacy is not enough in itself, it has to be seen as an adjunct to the general literacy required of all people.

14. The concept of a Computer Literacy Programme for the Commonwealth is interesting and badly needed, but operationally a formidable challenge. One approach, perhaps the simplest, would be to disseminate information on the successful British experiences to the other countries, assist establishment of contact, organize seminars and let developments in other countries to take their own pace, without any direct central coordination from an organization such as the CSC. This approach seems practicable and can be an adjunct to its current training activities involving microcomputer applications aimed at specialists. The impact of such an attempt would however be difficult to see, although it would require considerable effort. The alternative is to set up a mechanism to develop and conduct a Commonwealth computer literacy programme. This will need to be a joint effort of different participating governments, broadcasting authorities and regional and international organizations committed to mass education, distance teaching etc. Subject to the interests of member governments, CSC could take the lead in promoting discussions with appropriate organizations for investigating the feasibility of such an idea, but perhaps should not be involved in the direct operation of such an effort since the emphasis on mass education is not within its present remit. The Commonwealth Education Programme could be a better venue for coordinating such a programme.

15. For developing countries to participate successfully in such a programme, a very cheap and robust microcomputer, widely available would be a prerequisite. The present micros are too expensive for developing countries. The availability of micros will need to be backed by servicing networks. Broadcasting authorities and educational establishments will need to be involved in every country. Television and radio programmes with limited content can contribute very modestly

to learning . These media help seizing public attention, explain a little, and cause people to feel differently about computers and computing. Their essential advantage is that they can reach millions of people in their homes, capture their interests and point them towards learning. Television and radio programmes are therefore the most public part of any computer literacy programme. Equally important are other elements such as books, software, correspondence courses, the availability of cheap, versatile and robust microcomputers, etc. All these will require strong infrastructural support in participating countries, which may be beyond the initial capability of many developing countries. Unless such a programme is carefully planned, it may benefit only some sections of the population such as the urban dwellers , people owning TV sets, schools in urban areas, etc, thereby widening the literacy gap within various communities and income groups.

(h) Conclusion

16. The idea of a Computer Literacy Programme through distance teaching is attractive but complex. The first question that needs to be asked, is CSC the best organization to undertake such a task, or should it encourage another Commonwealth body whose primary vocation is education to consider the idea? Furthermore, the infrastructure in developing countries does not appear suited to a mass education programme widely available to different age and income groups and to rural and urban areas. It may therefore be preferable to encourage bilateral contacts between Britain and other countries to share experiences. CSC in cooperation with other bodies could also organize regional seminars on computer literacy programmes to sensitise policy-makers in Commonwealth countries. The idea of developing a cheap, robust and versatile microcomputer could also be considered further, keeping in view worldwide developments; the present microcomputers are sold at prices which include their full development costs and their manufacturers would therefore be in a position to sell these at a much lower cost, in the face of any competition, thus making any new initiative very difficult to take off.

17. On the basis of available information, it appears that any CSC initiative concerning a Computer Literacy Programme for the general public should be approached with caution. CSC should continue its efforts to serve specialist training needs aimed at postgraduate levels, and set up research networks in selected areas to promote Commonwealth cooperation in computer science and computer technology with specific applications in focus.

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Scientific Cooperation in the Commonwealth: The Role of Information Technology

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1. Introduction

Scientific and technological activities demand resources. These resources include facilities necessary to carry out experimental and theoretical studies; information from previous and related studies carried out in the past and elsewhere, and ready access to skilled personnel. The latter must provide the scientific creativity, insight and knowledge necessary to advance the subject and to operate and maintain support facilities.

There is a well established tendency for the most able scientists and engineers to gather in establishments which offer such resources and thereby create 'centres of excellence'. These in turn attract resources. There is a corollary that other establishments are denuded of talent and facilities.

Information technology (IT), described below, offers a mechanism to maintain a centre of excellence but allow its physical de-centralisation; in effect by maintaining good communication between facilities and individuals at a distance. Already individuals employed in IT industries in the developed countries are able to carry out some of their work at home. The opportunities are greatest in those disciplines which make most use of the twin components of IT, computers and communications. Fortunately, but to some extent inevitably, such subject areas are growing, as discussed below.

IT is an allowing mechanism, not necessarily the pressure for change. That is likely to come from the material advantage of individuals living in environments which are culturally, intellectually and climatically of their choice. The Commonwealth is well placed to take advantage of such opportunities. It contains centres of excellence in many fields. It covers a very wide area geographically and therefore embraces a range of population densities, climatic conditions and cultural backgrounds. It has a common language which is also the basis of almost all computer control languages. It has a history of interchange between member countries, and has some elements of a communication infrastructure to promote further development.

After expanding on the concepts mentioned above, some relevant trends are identified. A possible strategy for further action and its effects are then discussed.

2. Concepts

2.1 Information Technology is the acquisition, processing, storage and dissemination of vocal, pictorial, textual and numerical information by a combination of data processing and telecommunication techniques. The first provides the capability of storing and processing information, the latter the means of acquiring and disseminating it, so that the combination of techniques has been symbiotic. There has been convergence of the relevant technologies, catalysed by the availability of complex, reliable and in-expensive (through large volume production) micro-electronic components and hence equipment built from them. The compatability of digital techniques in data processing and communication technology has contributed to the convergence also.

2.2 Distributed processing. In the early days of computing the novelty of the technology demanded the creation of specialised computer centres with manual interfaces to the outside world. This was necessary because of the care which had to be lavished on them and the absence of a suitable, automated input-output methodology. The volume and rate of delivery of data and results and of their storage were compatible with these limitations. The development of IT has created a much wider range of possibilities. Processing can be accomplished at several points in a complex data gathering, assimilation, modelling, predictive, dissemination activity. A number of different compromises can be reached in practical systems.

2.3 The super-computer represents the current end-point of a development path which began with the first computer designed to carry out calculations much faster than was possible by human efforts alone. Super-computers in use at present have an architecture which encourages parallel processing and for some scientific and engineering problems can complete several hundred million calculations per second. Systems capable of ten thousand million such operations per second are expected to be available before the end of the decade. The exciting consequence of this is not the size of that number but the range of problems which as a result can be simulated effectively in a finite time by mathematical rather than physical modelling. The first such models involved fluid flow in weather forecasting and aerodynamics. Latterly, the rate and energetics of chemical and biological processes have begun to be modelled. The subject matter increasingly involves realistic (engineering) rather than idealised problems in inherently dangerous or inaccessible regimes in the oil and nuclear power industries for example.

2.4 Communication satellites represent a rapidly evolving development in telecommunications. In essence such a satellite is a microwave relay allowing exchanges between large areas of the globe. To achieve this it contains a number of transponders receiving signals in a given microwave frequency band and re-transmitting them after amplification at a different frequency. The satellite requires ground stations to receive and transmit these signals. The first such stations were massive; more recent ones, installed for example to serve individual businesses and hotels (for TV reception) in the USA have antennae which range from 10m to 1m diameter. Of greater importance, the cost of a dedicated voice grade channel capable of carrying data at a rate of circa 10K bps is of the order of $100 per annum (= $3\ 10^9$ bits/dollar). This figure includes the cost of both satellite and earth stations. Note also that the transmission cost is independent of distance.

3. Trends

It is certain that there will be a continuing growth in telecommunication capacity; locally through increasing use of cables - necessary to provide secure, high capacity commercial services - and over long distances using satellite communications. The latter will be driven in part by commercial pressures, notably the interests of multinational corporations and advertising in and serving of international markets. Furthermore the USA is sufficiently large to make satellite communications very attractive on their national scene, for similar reasons.

The costs of microelectronic circuits and of the computer hardware built from them will continue to fall. The performance of such hardware will continue to improve. Therefore the costs of processing will decrease; probably at a rate greater than that of communications. This, in isolation, is an argument for distributing computing power rather than concentrating it locally. However there

are specialised uses which demand some centralisation of function. Thus very powerful super-computers demand rapid access to data and storage of results to sustain their high operating rate; a wide distribution of the component parts is not conducive to this. Particularly when subject to rapid and frequent change, data management is much easier to achieve if a 'single copy' philosophy is adopted. Thus the demand for centralised data storage is likely to continue.

The costs of skilled people are rising, in the developed countries at least. The cost of software is also rising therefore.

4. Strategy

It is suggested that developments in IT will allow sustained growth of science and technology throughout the Commonwealth only if efforts are concentrated on the production of 'distributed centres of excellence' in several selected disciplines. In the short term this might be promoted through the installation of so-called Remote Job Entry terminals at universities and research centres in developing countries. These would be linked to computing facilities in the UK, Australia or Canada say, via satellite communication channels. Such terminals would allow access to computing power and information; the latter might include abstracts (at least) of the scientific literature.

The degree of complexity and sophistication in such terminals would have to be compatible with local maintenance capabilities. Large volumes of data would probably be exchanged by non-telecommunication methods. At present, UK Universities are able to gain access to computer resources in a manner analagous to that proposed. The scheme is administered by the SERC; a similar body would have to be identified to administer a scheme extending throughout the Commonwealth. SERC are also involved in a research project, UNIVERSE, designed to test various aspects of satellite communication.

Capabilities would be developed by upgrading the terminals to provide an interactive capability, and by providing local processing power. This change is taking place in the UK at present as so-called dumb terminals are replaced by micro-computers. Because of the falling price of hardware such micro-computers have the power of substantial main-frames a few years ago. As skills increased it is reasonable to expect that indigenious software industries would grow around universities equipped with such facilities. It is likely that these industries would compete effectively in the world software market. There is evidence of this in the Eastern Block countries who have skilled manpower but restricted access to sophisticated hardware.

In the medium term the possibility of providing a shared Commonwealth super-computer might be pursued. Again such facilities are available to UK universities and centres are being set up in the US and elsewhere in Europe. Good communication allows use of the facility at a distance. The range of problems being tackled is growing almost daily as the advantages and feasibility of numerical simulation are perceived. Old problems in chemical kinetics for example become tractable and new techniques for the identification of likely catalysts are being developed. Given access to the computing facilities, the key resource is skilled manpower. There is no reason to require juxtaposition of these if good communications are available.

INFORMATION TECHNOLOGY

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INTRODUCTION

Information Technology is a new and a powerful tool. Its potential power and pervasiveness has made it perhaps one of the most ubiquitous technological tool of this century. It has been termed as a technological revolution having the power to bring all the nations together to combat the worldwide problems of energy, ecological pollution, population and North-South disparity.

The expanding role of Information Technology emphasises the need for international scientific and technological cooperation and presents the only means of achieving significant contributions to this new technology from the developing countries. The developed countries have much to gain by means of trade and market expansion by involving developing countries in technological advance, while the latter would acquire the benefits of a new technology, skilled manpower, the ability to adopt and adapt the technology for its own purposes and even to establish indigeneous research and development facilities.

The basis of international scientific cooperation, in this paper, is thought to be one which aims to achieve a programme of research and development which is mutually beneficial to the countries party to any joint ventures. The implication of such ventures is to avoid mismatch of social and technological interests and to attempt to establish indigeneous research and development facilities in developing countries. This would require such programmes to enhance the scientific and technological expertise in developing countries through a suitable combination of training programmes which could range from information exchanges to extensive collaborative research and development schemes and exchange schemes for researchers and academics between universities and research centers.

Time frames for development programmes would depend on the standard of the technological base, availability of human resources, motivation for research and training and funds for financing research and collaborative ventures. In general short term programmes should attemt to establish simple to sophisticated technology and infrastructure whereas long term programmes should attempt to resolve the more sophisticated issues concerning the technology and should aim to combine the strengths of developing countries such as the inexpensive labour force in technological advances.

In this paper the following aspects of Information Technology are discussed:

1. Micro-electronics technology (i.e issues relating to LSI/VLSI development)
2. Software Engineering.
3. Micropocessor Applications

These topics are among the core subjects of all advanced institutions in the developing countries, and the success of the latest technological revolution may be said to be related to achievements in these fields.

1. MICROELECTRONICS TECHNOLOGY

1.1 Objectives

The objectives of scientific collaboration is to achieve a wide range of process and technology development in the design and manufacture of Large-Scale and Very-Large-Scale-Integrated (VLSI) silicon systems. The area of microelectronics manufature and application involves research into sophisticated and efficient methodologies which allow quick and reliable design of systems. Already a lot of work has been done but more research is required to improve the existing standards and to gain proficiency in design automation, which would lead to quicker and more reliable yield of integrated circuits.

Joint ventures in this area would involve developing design methodologies, computer-aided-design tools, analysis and testing techniques, metallurgy for package development, automated optical and electro-optical equipments, specification techniques, specification languages, design verification tools, failure analysis techniques, computer modelling and simulation facilities.

1.2 Time Scale

Short term cooperation would lead to (a) installing simple CAD tools and training workers in the field to use them, (b) involving researchers and technologists in the design and fabrication of components which could contribute towards some project such as in computer architecture or communication systems, (c) defining research areas which would concentrate on the use of the technology for application within the country. This is an essential step if the venture is to be viable then it should be accompanied by efforts to find and promote a market locally within the country, (d) defining research areas which could support work done in more industrialised nations, (e) defining courses and training schemes and establishing centres of research and development, within the country, (f) providing "hands on" experience courses for the purposes of training, both in developing and developed countries.

Long term cooperation could hope to resolve the more sophisticated issues in the field such as producing methodologies and tools for design automation, specification, verification, fault tolerant design, testing etc. as well as pursuing the foundations laid down for assimilating the technology within the social structure of the country.

1.3 Modalities

Microelectronics development would require cooperation at all levels. The scope of this subject is vast and cannot succeed without collaborative research. Exchange of researchers and academic staff is essential for development and training. There is a strong case for industrialised countries to study the directions for VLSI advancement which could ultimately allow its absorption into the mainstream of activities of developing countries.

1.4 Benefits

VLSI development brings with it the possibility of building electronic circuits which have improved performance characteristics in terms of size, speed, reliability and complexity. These advantages enhance the scope of its application, compared to the earlier technology. Thus allowing computers and digital systems to be built which are more powerful and more efficient than before. Such devices would directly benefit the scientific and technological advancement which in turn brings improvement in social and economic conditions of the nation. VLSI technology will be most effective in improving the standards of information processing.

1.5 Infrastructure

The equipment cost for microelectronics fabrication may prove prohibitive to many developing countries. A fully equipped research research centre could service the fabrication demands of a network of research centres. Computer communication facilities are essential in order to be able to transfer and to share CAD tools and software conveniently, and effectively, between the centres.

2. SOFTWARE ENGINEERING

2.1 Objectives

The object of scientific cooperation is to produce quality software and its specification, implementation and management.

Software development is of considerable importance to developing countries as it is human skill intensive and therefore more adaptable to most of them. However without adequate training and tools the possibility of any significant progress in this area is minimal.

Joint ventures in software engineering should cover areas such as: investigation of software metrics such as size, complexity, quality etc. of systems and program evolution. Modelling of the software engineering process and production of tools for planning and management of software. Study and control of software complexity (with a view to understand and maintain software produced by other people). Develop tools for specifying problems and converting such specifications into operational systems; developing methodologies for program testing and verification.

2.2 Time Scale

Short term cooperations should aim to install the more efficient of the existing systems and software tools for micro, mini and mainframe computers. Training schemes for the use of these systems and for producing high quality software should be concomitant with such programs of installation. The need for developing countries to learn to produce quality and to manage software projects effectively is immediate therefore short term schemes should aim to establish a suitable base for such activities.

Long term ventures would aim to solve the more sophisticated problems such as techniques for measurement and control of software complexity. The development of data bases to help produce and maintain software for a large range of applications. The development of 'problem oriented' programming languages and tools which would allow higher productivity and require less training for programmers.

2.3 Modalities

Information exchange could be one of the chief methods of training and educating software engineers and scientists. Where an international computer communication network can be established, practical projects would be taken up jointly between research centres in more than one countries. Parts of completed projects or software tools developed in one centre could be ' mailed' for inspection or use by another centre. This would be an effective way of developing collaborative projects.

Courses in Software Engineering practices should be arranged such that experts in the field can inform and stimulate researchers to produce better software aids and methodologies.

2.4 Benefits

The benefits would be immediate to many countries within the Commonwealth who are (or intend on) producing software for use by more developed countries. Such countries would be able to expand the scope of their software projects and be able to take on more sophisticated projects in the future.

In the long run, a growing software industry would produce skilled manpower, improved computer systems and capacity to generate indigenous technology.

2.5 Infrastructure

The infrastructure exists in part, at least, in some of the countries. Courses arranged at regional research centres should be effective in training engineers and scientists. Groups and individuals should be able to access literature on Software Engineering from these centres. This is essential for a more widespread education and training in producing high quality software.

A network of research institutes connected with the research centres could use materials from the centre for research as well as training. Training should be extended to universities, with courses on Software Engineering. At all times the courses should aim to study the practical aspects of software generation, maintenace and management.

3 MICROPOCESSOR APPLICATIONS

3.1 Objectives

The scope of work in the micropocessor applications is the widest amongst the 3 topics being discussed in the paper. Its immediate consequences would be even more far reaching than that of Software Engineering. The areas which could see the application of micropocessors (though this list is by no means complete) are: Knowledge-Based-Systems Man-Machine Interface, Agriculture and Fisheries, Industrial Control, Education, Business (especially small-scale), Medical Instruments, Data Acquisition and Entertainment.

Micropocessors are being applied in various disciplines in most countries. However, lack of development facilities and expertise makes such applications limited in their scope. Joint ventures with developed countries would provide the motivation to many developing countries for generating more sophisticated systems. Such systems may be developed and marketed for markets abroad but may later be adapted for internal use.

3.2 Time Scale

Short term cooperation should aim to educate and train researchers in the techniques of designing systems. Long term goals should be set for research and development into adapting technologies for micropocessor applications. The use of Knowledge-Based Systems and improved Man-Machine Interface would eventually make the technology more accessible , even to non technical members of the society and thereby add impetus to the growth of Information Technology

3.3 Modalities

The methods of research in this area would need involvement of a more diverse range of technologists than those mentioned for VLSI or Software Engineering. Research Centres, involved in both applied and fundamental research, should involve themselves through exchange programmes to define the areas of application for micropocessor based systems.

Engineering and Technical researchers should set up joint collaborative programmes where they could study how systems could be developed, both on the software and hardware levels, to produce highly efficient systems.

3.4 Benefits

The use of micropocessors is aimed at improving efficiency and speed in technology. Joint programmes would not only allow participating countries to adapt and adopt sophisticated micropocessor systems technology, but also allow them to generate indigenous ones.

3.5 Infrastructure

The infrastructure should be set up with research institutes, research centres and groups working in the area. Rural centres where micropocessor could be used for collecting data on agricultural indutries should be set up as well.

Potential for Commonwealth Cooperation in Information Technologies

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Most of the technological achievements of the past decade have depended on computer, but throughout the next decade information technology will assume an even more pervasive role. (Information technology may be broadly classified as the convergence of computing, communications and micro-electronics). In the 1990's when information technology will be in widespread use, information processing systems will be central tools in all areas of social activity, such as: industries, administration, defence, education, culture, and most importantly, home activities.

Japan, in the so-called information revolution, occupies a position analogous to Britain at the start of the industrial evolution. Japan and the other countries of south-east Asia, regard information technology as the enabling technology of the 1990's forming the basis of what is being called "intelligent" consumer electronics (eg. televisions and video recorders responding to voice commands, as well as sophisticated learning aids etc); the next generation of wealth-creating consumer products. Not only will it be the enabling technology for the emerging information industries but also the secondary (manufacturing) industries and the primary (agricultural) industries.

If a country chooses not to invest in the future information technologies then it is implicitly accepting a role of a non-industrial country.

Technologies

Information technology, recall, represents the convergence of computing, communications, and microelectronics, giving a full integration of computer-communciations. Hardware developments in communications already allow all the computers of a single organisation, beit IBM or the major universities in a country to be linked together. Each year more and more computers and in an increasing range of countries can interact, exchange information and work together. Over the next decade it is easy to envisage all telephone, telex, and computers being integrated to something akin to an information processing equivalent of the telephone network. Microelectronics allows the nodes of such networks to be: powerful, reliable, compact and inexpensive; these are also the requirements of intelligent consumer electronic products.

In the software area the major development in the next decade will involve so-called knowledge-based expert systems using artificial intelligence techniques. Expert systems embody modules of organised "knowledge" concerning specific areas of human expertise. They also support sophisticated problem-solving and inference functions, for the purpose of rendering the users intelligent advice on one or other specialised topics.

Future expert systems will also provide human-oriented interaction in the form of natural languages, speech and picture images. For example, an expert system for medical diagnosis could operate in a way analogous to the way a physician, a surgeon and a patient interact and use their knowledge to make a diagnosis.

Given these advances in technologies it will soon be possible to have an inexpensive (£100) microcomputer system that is able to support sophisticated expert systems for education and training.

Scientific Cooperation

The potential for Commonwealth cooperation in information technology may be broadly classified into 3 areas:

1. Education - the establsihment of basic computing education in schools and colleges. Here a good model is the UK Government's Microcomputers in Schools Programme.

2. Industry - the establishment of basic IT industries, as for example to assemble the components of microcomputers. By protecting home markets such fledging industries could rapidly expand, as is happening in Brazil.

3. Research - the establishment of research and development centres that (initially) adapt information technology (educational) products for local usage and also provide education and support services. Later such centres could independently develop their own IT research programmes. The Japanese Government is recognised in being the leader in government directed IT research.

Fortunately, these 3 areas are mutually supportive. To undertake wide-spread teaching of computing in schools it is necessary to have locally tailored microcomputers and educational software. To defray this cost it will be necessary to assemble the microcomputers locally, and to support this IT education and development, it is clearly necessary to have some local educational/manufacturing centre.

With the appropriate external support, a small centre could be established at a national university to support these education, industry and research activities.

A Programme

Given the spectrum of industrialisation of the member countries of the Commonwealth, the Science Council should be well placed to promote a broad programme of educational, industrial and research collaboration in information technologies. The more advanced countries might collaborate in an IT research programme analogous to Britain's Alvey Programme, while the least industrialised countries would collaborate in IT education. The most urgent task would seem to be establishing a basis for information technologies, notably education in these least industrialised countries.

The following programme is proposed. The Commonwealth Science Council in conjunction with a UK University should establish a small research group or centre in the UK to develop a "Commonwealth" microcomputer and associated educational software. Each country participating in the programme would send 2 people to the centre, whose task would be initially to develop the microcomputer system and specialise it to their country's particular needs and then, on their return, to establish at their national university a similar education/research centre. This microcomputer system would then be assembled and maintained locally, and form the cornerstone of IT education in these Commonwealth countries.

Ideally, these centres would have educational, industrial and research components. Using modern computer networks, all the centres cooperating in the programme could communicate on a daily basis, providing mutual support and facilitating the rapid distribution of software.

Although it is important initially to have dedicated staff working on the design of the "Commonwealth" microcomputer system, after the establishment of the local centres the UK group could be disbanded or could be set the task of developing the next generation of systems.

Further Reading

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EPIDEMIOLOGY OF COMMUNICABLE DISEASES

Problems and Opportunities

for

The Commonwealth

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I NATURE OF COMMUNICABLE DISEASE EPIDEMIOLOGY

II THE SCOPE OF THE PROBLEM

III PROBLEMS AND OPPORTUNITIES IN RELATION TO SOME PARTICULAR INFECTIONS

- i viruses
- ii bacteria
- iii protozoa
- iv helminths
- v disease vectors, reservoirs, and the human host

IV THE OPPORTUNITY FOR PROGRESS

V THE COMMONWEALTH EPIDEMIOLOGY PROGRAMME

EPIDEMIOLOGY OF COMMUNICABLE DISEASES

This paper sets out the needs and opportunities for epidemiological work in the Commonwealth to contribute to human health and development. It deals with the use of epidemiological methods and the study of epidemiological problems due to communicable disease, and the rapid progress now possible in this relatively neglected field.

Recent progress in molecular biology will lead to new vaccines needing field trial and more specific diagnostic methods of great epidemiological value, while important new pathogens have recently been discovered. Both the problems and the methodological advances make this perhaps the most exciting time for communicable disease epidemiology this century. The Commonwealth is particularly suited to take the initiative in developing this highly cost-effective field and could make a substantial impact.

I THE NATURE OF COMMUNICABLE DISEASE EPIDEMIOLOGY

The word 'Epidemiology', like 'engineering' covers a great variety of activities and some discussion of these is needed as a background to specific proposals for co-operative action. Epidemiology really covers at least two aspects of disease in populations. One is the 'epidemiological method' as a technique for determining aetiology. By studies of a defined disease in

the community it is hoped to find clues as to the, previously unknown, cause of the disease being investigated. The great achievements of this approach have been with the non-communicable diseases: smoking and cancer of the lung, asbestos and mesothelioma, for example. But the other aspect of epidemiology is concerned with understanding the behaviour of diseases of known aetiology, in the human population and community. Such understanding provides the scientific basis for communicable disease control. There is a spectrum of work therefore from relatively basic research on epidemic theory and disease measurement through to highly applied operational research on the optimization of control procedures within a health service and the evaluation of control.

All these components form part of communicable disease epidemiology. In the case of endemic diseases such as malaria, schistosomiasis and leprosy, epidemiological research is needed to determine the best methods for control. For other infections such as cholera, typhoid, dysentery, and lassa fever, the need is for outbreak investigation. The evaluation of immunization programmes and other control procedures is a third area, while the design and operation of surveillance systems is a fourth component of communicable disease epidemiology. The diseases of wild and domestic animals transmissible to man, the zoonoses, are a special group of infections in terms of the scientific and practical problems they raise, and the vectorborne parasitic and viral diseases such as malaria, yellow fever, sleeping sickness

and leishmaniasis also require special expertise.

Communicable disease epidemiology has had a varied history. Most of epidemiology was concerned with communicable disease until the end of the second world war. Then the advent of antibiotics, other effective antimicrobial chemotherapy, and residual insecticides such as DDT, caused a wave of excessive optimism over the struggle against communicable diseases. Eradication campaigns against malaria have unkindly been said to have eradicated malariologists rather than the disease, and the chronic scarcity of epidemiologists has become even more severe. In many developing countries the career structure is almost absent, and since field epidemiology is incompatible with the type of after-hours private practice that is necessary to provide adequate income in many developing countries, there is a combined problem of career structure and training in the absence of an epidemiological tradition.

In other Commonwealth countries there is a tradition of excellent communicable disease epidemiology from earlier days - in Kenya, India and Ghana for example - which needs building up, and the United Kingdom has a strong tradition of outstanding epidemiologists.

Viewing the developing countries of the Commonwealth as a whole, communicable disease epidemiology is not only one of the sciences basic to medicine that needs most strengthening, it is also the most cost-effective in relation to improving human health and

contributing to socio-economic development. The epidemiologists who planned and directed the smallpox eradication campaign were very few in number but they have saved more lives per head than almost any other workers in medicine except perhaps those who discovered penicillin.

II THE SCOPE OF THE PROBLEM

The communicable diseases are of immense importance. In the tropics they are the principal cause of death and disability. Throughout the third world respiratory infections and diarrhoeal diseases, sometimes together with malaria, head the list of causes of death. Communicable diseases and malnutrition are together responsible for most of the difference in mortality patterns between developing and industrial countries. They also cause a vast amount of morbidity. There are more than 1,000 million cases of respiratory infection and about 1500 million of of infective diarrhoeas annually in the world. Several helminth infections are very prevalent so that at any time there are about 200 million cases of schistosomiasis, 800 million people infected with Ascaris globally and, prior to control measures being instituted, there were 100 million cases of malaria in India each year with possibly a million deaths. Even now there are probably between 5 and 10 million malaria cases annually in India in spite of great efforts at control.

The range of pathogens causing communicable diseases is wide, including bacteria, viruses, rickettsiae, chlamydia, protozoa,

the various groups of parasitic worms or helminths, and fungi. The vectors of some of these include mosquitoes and other biting flies, ticks and mites, aquatic and amphibious snails while the animal reservoirs of infection are very diverse.

Historically, the acute infectious diseases with a high mortality have attracted most attention. Diseases are important as a result of both their actual and their emotional impact on human populations. Some diseases such as plague and cholera retain their dreaded reputation though their actual impact is now much diminished. Acute lethal diseases engage the imagination more readily than chronic illness. However, they are relatively tractable epidemiologically and many of the outstanding problems concern endemic and chronic infections. Death rates are often used as an indicator of the importance of an infection but a chronic debilitating illness such as malaria or a high incidence of an acute non-fatal illness such as diarrhoea or the common cold may have a greater impact on the social and economic well being of a human population. The scientific problems are greater: it may be difficult to design and implement a good trial of two measles vaccines in the community; it is very much more difficult to design a trial of a leprosy vaccine where the frequency of new cases is low and the incubation period of the disease may be seven years. Thus the chronic infections may lay a heavy burden on the health services, cause widespread morbidity and disability leading to economic loss as well as human tragedy, and pose important and interesting epidemiological problems.

A further need is for epidemiological surveillance. In developed countries the available morbidity and mortality statistics allow certain deductions to be made and perhaps techniques of cost-benefit analysis can be applied. Quantitative data are usually unavailable in developing countries. Even if crude death rates and case fatality rates can be obtained, the number of persons with the disease in the total population is often a matter of guess work. Even among Commonwealth countries such data are rare and few even contribute to the W.H.O. statistics.

In the developed world, downward trends in mortality from many infectious diseases have occurred in the past without any planned disease-related intervention. This reduction in morbidity and mortality from infectious and parasitic disease has been associated with a scale of infrastructural investment unavailable to the rest of the world. The provision of sewage systems, water for washing and the social imperative for their use together with the reduction of the burden of ectoparasites such as fleas and lice and the improvement in nutrition have all contributed. However, though non-specific unplanned improvements may have been helpful in the past, it is neither possible nor desirable to continue to progress in this way. Our understanding of many infections has reached the level at which planned control is possible. If the methods available for disease control are to be applied worldwide, targetted programmes are essential. This requires both skilled epidemiologists and good quality epidemiological data, though the success of the small-pox

eradication programmes well illustrate that the former can to some extent compensate for the lack of data and that complete information is not needed before planning can start. Where control programmes are in operation they are often ineffective or of low efficiency. Epidemiological evaluation is a precondition for their improvement.

III PROBLEMS AND OPPORTUNITIES IN RELATION TO SOME PARTICULAR INFECTIONS

The scope of the problems is therefore very great. The most striking features have been the dramatic changes in the specific components of the broad problems in recent years. New disease agents have appeared, parasites have become resistant to drugs and insect vectors to pesticides. New vaccines have been made and many are on the way. Huge water resource development projects have changed the pattern of disease over great areas of Africa, Asia and Latin America. Rapid tropical urbanization brings changes in lifestyle, environment, and diseases. These effects are best seen when the various infections are considered in greater detail.

(i) Viruses

The advances in molecular biology of the last two decades have had a great impact on virology. In the epidemiological field they have raised new questions not only related to viruses: the epidemiology of oncogenes does not yet exist and that of the

plasmids bearing drug resistance still has great potential for development. Present understanding of the structure of the influenza virus has provided a basis for the epidemiology of antigenic variation. The use of increasingly sophisticated techniques such as monoclonal antibodies and DNA probes is allowing much more detailed epidemiological studies to be undertaken for many viruses.

Several new viral causes of disease have been discovered in recent years and their epidemiology remains to be solved. Ebola virus is a clear example. The rotaviruses are not only relatively recently described as causes of human disease but are very common. They cause as much as 20% of diarrhoeal disease in children. Similar viruses cause disease in animals. Growth of this group of viruses in tissue culture has only recently been achieved. A vaccine is an attractive prospect. However, these viruses have a segmented genome and these studies in this area hold the promise of all the problems and interest of studies with influenza viruses. It is likely, because of the number of types involved, that nucleic acid probes will be of particular value in the examination of the epidemiology of these viruses.

The hepatitis viruses have also been the subject of much recent progress. That causing hepatitis A has recently been grown in tissue culture. A vaccine is available and further developments are in prospect. The growth of the virus means that large amounts are available for study and its molecular biology will

soon be understood. It is an RNA virus but it will be possible to control the nature of vaccines by use of cloned genetic material. Chemical synthesis of the relevant antigens is a future prospect. In case of hepatitis B, a vaccine based on material isolated from the serum of infected people is currently available. However, the limited amount and cost mean that it cannot be used in the tropics for the prevention of primary liver cancer. Clones in E. coli and studies on the chemical synthesis of viral pepticles render better and cheaper vaccines an immediate prospect. The design of trials, especially for cancer prevention, raises many epidemiological problems. A fascinating discovery is the Delta agent; a hepatitis virus that only occurs in conjunction with Hepatitis B virus. The importance and interest of such associations is well illustrated by Rous sarcoma viruses. The use of specific diagnostic procedures have resulted in the discovery of other causes of hepatitis whose epidemiology remains to be studied.

The dengue viruses, which are spread by culicine mosquitoes in many parts of the tropics, have become of increasing importance due to the occurrence of a shock syndrome and haemorrhagic fever, especially in children, so that this is the second commonest cause of child admission to hospital and death in parts of Thailand, for instance. The pathogenesis of the haemorrhagic fever is unclear, but may depend on superinfection by one strain of virus in those with antibodies to another strain of dengue. Here again is an epidemiological problem only soluble by a combination of recently developed laboratory techniques and

expert field epidemiology.

(ii) Bacteria

The introduction of antibiotics and other antimicrobial agents for the treatment of infections inhibited interest in the study of the mechanisms of bacterial pathogenicity and it was not until the 1960's that interest started to revive. The enthusiasm generated by the demonstration of cholera toxin together with advances in molecular biology have resulted during the past twenty years in an understanding of the molecular mechanism of microbial virulence. These insights can be exploited in analysis of the variation in disease patterns observed in the tropics and in developing methods of prevention.

Since the earliest days of bacteriology the study of Vibrio cholerae has provided insights into transmission of bacterial infections. More recently the success of studies on the pathogenesis of cholera has stimulated a whole range of investigation on the pathogenicity of bacterial infections. The genes coding for cholera toxin have been cloned and this has resulted in genetic probe techniques for the detection of the gene coding for the toxin by DNA homology. As the gene that codes for the heat-labile toxin of Escherichia coli is very similar this probe can be used in epidemiological investigations of E. coli diarrhoea. The potential value of this approach has led to the development of a range of other probes for the

virulence factors of other bacteria including the heat-stable toxin of E. coli.

The improvement in our understanding of the virulence factors of V.cholerae has reawakened interest in cholera vaccines. The present vaccine is unsatisfactory. Vaccines based on purified virulence factors and upon chemically mutagenized or genetically engineered strain of V.cholerae are becoming available and will need to be properly tested. The outcome of these studies will have profound influence on the development of vaccines for protection against other enteric pathogens.

Mycobacterium tuberculosis is one of the most important and best understood of bacterial pathogens. In well conducted epidemiological trials BCG vaccine has been shown to provide protection to some populations but not to others. It seems that BCG is ineffective in populations that have been heavily exposed to other mycobacteria. Until the reason for the failure of BCG to protect are fully understood the control of tuberculosis will not be possible in the third world, in spite of effective treatment.

Although the significance of many bacterial pathogens has been established for many years the importance of others has only recently been realised. Campylobacters are isolated only very seldom in the aerobic as anaerobic culture systems routinely used for isolation of bacteria. Before 1970 C.fetus was a bacteriological curiosity, of limited interest in vetinary

medicine. The realisation that these bacteria are microaerophilic together with the development of reliable methods for their isolation and the use of these methods in clinical laboratories, has resulted in the recognition of C.fetus ss jejuni as a major pathogen of greater importance than all Salmonellae.

Our understanding of Campylobacter infections is at an early stage. Various toxins and invasive factors have been described as contributing to pathogenesis. Very few satisfactory epidemological investigations have been completed. There is a suggestion that the prevelance is less in arid regions.

This is a field in an active stage of development. It is important to ensure that improvements in our understanding of the biology of infection and the molecular biology of the organism are translated into effective measures for the control of this disease.

The range of diseases discussed here are not exhaustive. Other newly discovered pathogens that might be mentioned include Legionella. Vaccines that require proper epidemiological evaluation include pneumococcal, meningococcal and perhaps gonococcal capsular carbohydrate preparations and a mutant of Salmonella typhi. The application of the techniques of molecular biology to the study of the pathogenic process continue to advance our knowledge. The extent of the benefits from these

advances depends to a large extent on proper epidemiological study and control.

(iii) Protozoa

Malaria dominates the protozoal diseases, with over 100 million new infections and a million deaths a year. Though eradicated from Europe (except for one part of Turkey) and North America, it is resurgent in Asia and was never controlled appreciably in sub-Saharan Africa. In India, for example, there were perhaps 100 million cases annually in the 1930's, 167,000 at the height of eradication attempts in 1963, and back to around 8-10 million cases a year a few years ago. But the great worries are two: in south-east Asia and Colombia the parasites have been resistant to chloroquine (the best treatment and a good prophylactic) for many years. This resistance has spread, in Asia reaching India, Burma and Bangladesh, and it has now appeared on a significant scale in Kenya, Tanzania and Malawi. Also resistance of the vector mosquitoes to DDT and other residual insecticides has become widespread. Consequently control is very difficult and requires great epidemiological expertise which has been almost lost due to failure of recruitment to malariology during the eradication campaigns.

Progress in producing malaria vaccines is now both rapid and exciting, with possible vaccines against 3 different stages of the life cycle, and monoclonal antibodies enabling very specific epidemiological analysis. The opportunities for better

understanding are likely to be only exceeded by the need to design trials of candidate vaccines in the field. Among other protozoa, the antigenic variation strategies of the human and animal trypanosomes have been the subject of great molecular biological activity. The next stage will be to apply the results to epidemiological research. The sleeping sickness trypanosomes remain a threat to much of Africa while the American trypanosomes (responsible in all probability for Darwin's ill-health as well as the disability of many million people) pose many unsolved epidemiological problems, now soluble with the monoclonal antibodies and purified antigens becoming available.

The amoebae causing dysentery have been epidemiologically incomprehensible until recent isoenzyme work has separated out pathogenic and non-pathogenic strains whose separate epidemiology is now tractable but not yet done.

Leishmaniasis has recently been resurgent in India, and is being found to have a much more widespread distribution than had previously been realised, appearing in most tropical countries. The variety of its disease manifestations, from lethal kala-azar, through mutilating espundia to the cutaneous ulcers of tropical sore, pose many epidemiological problems. The last year has seen monoclonal antibodies and gene probes being developed that can make epidemiological analysis possible. Moreover, the clear experimental evidence of genetically controlled host variation greatly affecting the disease patterns observed, has implications

for the epidemiology of leishmaniasis (and of leprosy) in man that await full investigation.

Giardiasis has recently emerged as a common cause of chronic tropical diarrhoea; its epidemiology in sporadic temperate country outbreaks is well studied, but its role in tropical paediatric malnutrition is not yet understood.

Among the protozoa therefore the position is one of great - in the case of malaria, vast - practical importance of the diseases, complex agents of disease, recent progress in their taxonomomy, genetics and the molecular biology of their antigens, and a need to apply these results to epidemiological problems. This is limited by the scarcity of trained epidemiologists.

(iv) Helminths

The parasitic worms, or helminths, raise a different group of epidemiological questions at present. They are, in a special sense, quantitative infections in that the worms do not as a rule proliferate to the adult stage within man, and the number of worms acquired by the individual, the intensity of his infection, is a main determinant of disease. For some helminths there is no satisfactory form of chemotherapy, but for others recent improvements in drug treatment raise the most pressing epidemiological questions as may be seen from a few examples.

The human schistosomes affect 200 million people and are on the increase as a result of water resource development projects. In the last few years, approaches to schistosomiasis control have changed greatly. Molluscicides to kill the intermediate host snails have become very expensive while drugs safe for large scale treatment have been developed. The strategy of chemotherapy in control has yet to be fully worked out and this provides may epidemiological issues of both theoretical interest and practical importance. Similar problems are raised by many gastrointestinal worms for which good drugs exist, and where treatment of the sick individual is clearly understood but where the correct strategy for using drugs in transmission control is very unclear. Simple recurrent treatment has not been a success unless carried out in accordance with a careful epidemiological strategy and ancillary measures to reduce transmission.

By contrast, no safe and effective drugs exist for onchocerciasis, or river blindness, and such success as has been achieved in West Africa by the massive control programme there has been due to insecticidal attack on the vector. This is now showing resistance to the insecticide used, and the transition from the very expensive stage of overall vector control to a lower cost containment and consolidation strategy will require epidemiological expertise of a high order.

The relation between infection and disease in the case of chronic helminth infections is not immediately obvious, and careful

epidemiological analysis is needed if their effect on socio-economic development is to be adequately understood.

(v) Disease vectors, Reservoirs and the Human Host

Traditionally, communicable disease epidemiology has focussed upon transmission of the microbial or parasitic agent of disease. But such a view is too narrow for present needs and attention has to be given to the vectors and intermediate hosts of those infections transmitted by insects and snails, to the animal reservoirs of such infections as rabies, and to the genetic, behavioural and environmental aspects of human susceptibility to infection and immune responses. Only a few of these can be illustrated here.

The eukayotic parasites of man, both protozoa and helminths, have stages in their life-cycle outside the human host and these are temperature dependent. Often these developmental stages take place in either insects or water snails. Arboviruses such as yellow fever and dengue are also transmitted by mosquitoes.

The ecology of insects of medical importance received detailed attention prior to the introduction of residual insecticides when environmental control was the only possible approach. The development of resistance to insecticides, both biochemical and behavioural (avoiding the places where the insecticides are sprayed) has both revived interest in environmental and biological control of insect vectors and has also raised

epidemiological questions of the strategy for avoiding or delaying the emergence of resistant populations. Both field experiments and mathematical models are needed.

Local concern in Britain over the risk of rabies importation has highlighed the problems posed throughout the developing countries of the Commonwealth from zoonoses in which a vertebrate reservoir of infection exists. For example, in Grenada the reservoir of rabies is the mongoose which may survive an attack; in Barbados leptospirosis is an intermittent zoonosis causing lethal infections in man and where the animal reservoirs are of bewildering variety. Marburg, Ebola and Lassa viruses are all zoonoses but the detailed epidemiology remains unclear, while the leishmaniasis show varying zoonotic patterns in different habitats throughout the tropics. Epidemiological and zoological expertise have to be combined in any effort to understand them.

The human host of these many communicable diseases is often poorly studied, surprisingly! Only recently have the patterns of human water contact and excretory behaviour that underlie transmission of schistosomiasis, cholera and hookworm, begun to be fully investigated. The inter-relation of infection and malnutrition is crucial in determining the survival or death of young children but is still in need of much further epidemiological study.

In the last few years the genetic basis for variations in the

occurrence and severity of human infections has begun to be tractable. Animal systems have allowed genetic analysis of the basis of resistance to infection, and recent progress in the molecular genetics of the major histocompatibility complex has given clues to the genetics of susceptibility, resistance, and vaccine responsiveness. This now has to be studied in human populations by epidemiologists using the newly available methods of the molecular geneticist.

Lastly, the communicable disease pattern of most countries is changing rapidly as a result of socio-economic development and its associated environmental changes, whether in irrigation schemes, urbanization, or agriculture. The epidemiologist needs not only to understand the effects of these changes on disease patterns but also to devise methods to minimize the adverse effects on health that may otherwise occur.

IV THE OPPORTUNITY FOR PROGRESS

Though the problems are great the opportunity for progress is real and probably greater than in the past. The measures at present adopted by W.H.O for the control of communicable disease high light the problems but also suggest some solutions.

The Expanded Programme for Immunization (E.P.I.) is concerned to facilitate the use of existing vaccines in developing countries. The hope of perhaps repeating the success of the smallpox eradication programme has focussed concern upon the distribution

of measles vaccine but diphtheria, pertussis, tetanus triple vaccine (DPT), polio vaccine and BCG are actively promoted also. This may be regarded as an example of the transfer of technology but to be useful must entail developments in the primary health care infrastructure in the developing country. Experience with BCG has clearly shown that results of temperate country field trials cannot be transferred uncritically to the tropics. There is an epidemiological gap between the laboratory and the health service which has to be filled by applied research of a high standard. This need has been recognized by the E.P.I. and by the WHO programmes for tropical diseases research and diarrhoeal disease control, but they cannot cope alone with the scale of the problem.

The present need is for communicable disease epidemiologists able to utilise and capitalise upon these international initiatives. It is now widely accepted that work in communicable disease epidemiology deserves a high priority and that the immense burden of infective disease is a major drag on socioeconomic development. But there are far more positive reasons for seeing the development of epidemiology as a priority. Discoveries made in the last few years, as shown above, have opened up great opportunities for rapid epidemiological progress, in five directions at least

(i) New aetiological agents have been discovered, especially causing acute diarrhoeas (rotavirus, toxigenic Escherichia coli, Campylobacter) and a series of new

diseases have become apparent (Ebola, Marbug, Lassa viruses, Legionella.)

(ii) Molecular genetics is leading to the production of new, highly specific diagnostic tests for presence of the genes coding for microbial virulence factors so that powerful new diagnostic tools for epidemiological use are available.

(iii) The methods of bioengineering are opening up possibilities of improving existing vaccines and developing vaccines to many tropical pathogens. The evaluation and use of these will require very high levels of epidemiological skill.

(iv) New chemotherapeutic agents for helminths, and increasing drug resistance among protozoa require detailed epidemiological and genetic study, including mathematical models, for the effective utilization of chemotherapy in control.

(v) The rapid progress in research on oncogenes raises the possibility of a developing epidemiology at the interface of cancer and communicable disease.

Moreover, within epidemiology itself the availability of powerful microcomputers usable in developing country situations, and the elaboration of epidemiological techniques such as case-control

studies and their transfer from chronic disease applications to communicable disease work, also open up new opportunities for progress.

V THE COMMONWEALTH EPIDEMIOLOGY PROGRAMME

The subject of communicable disease epidemiology provides an almost unique example of an opportunity for scientific cooperation to aid development in which there will be mutual benefits: the unhappy model of a one way flow of science is not applicable here. There is expertise in the biological and molecular biological sciences in the industrial countries of the commonwealth; there is epidemiological expertise particularly in the United Kingdom, but the field opportunities for research and much of the field experience are to be found in the developing countries of the Commonwealth.

A successful programme of scientific cooperation in communicable disease epidemiology will involve at least four components.

1. Collaborative research between countries at different stages of socioeconomic development

2. Training, or rather higher educational, activities both in the developed and developing countries in the fields of epidemiology and of the laboratory backup for good epidemiology. The importance of adequate laboratory

backup is well illustrated by Campylobacter, discussed above.

3. A specific attempt to recruit young and outstanding biomedical and other research workers into this neglected field, to raise its status to match its importance for better health.

4. An attempt by the Secretariat to influence favourably the creation of career structures for those who wish to be academic or applied epidemiologists.

Such a programme would benefit all those involved because their expertise and facilities are of a complementary type. It would bring together all those needed to tackle the problems in a comprehensively and effective manner. It would generate work of direct large-scale relevance to the health of the populations of the Commonwealth. The benefits should therefore include healthier people, a core of well-educated epidemiologists capable of maintaining national expertise, and a network of scientists able to contribute to different aspects of the advanced epidemiological understanding and control of microbial and parasitic disease.

The programme would need to involve both scientific research workers in Universities and in the institutes attached to Ministries of Health. The problems are so large and the opportunities so many that any able research worker in the

general area, given time and basic facilities can make a contribution, but the programme should focus on building up national or regional foci of expertise and training that can have a long-term influence. Such a programme would have both short and medium term elements.

(A) In countries with a career structure, a short term focus on selection and training of outstanding young doctors and biomedical scientists should be combined with medium term institutional collaboration to build up a stable base with the necessary critical mass of workers.

(B) In countries without a career structure, a long term commitment to the development of the institutions is needed to support such a structure.

In conclusion, it is seen that in terms of both health needs and scientific opportunities, communicable disease epidemiology is a field suitable for, and liable to benefit greatly from, a Commonwealth initiative.

Epidemiology - Protozoal and Helminthic

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Introduction

The scope of epidemiology in understanding the protozoal and helminthic diseases throughout the Commonwealth involves all branches of epidemiology, ranging from the simplest form of descriptive studies to computer simulations of mathematical models and from case-control studies of causal factors to community trials of vaccines and therapeutic agents.

The epidemiological research needs vary greatly from one disease to another, e.g. in schistosomiasis with the recent development of improved quantification and simplified diagnostic methods combined with the new highly effective and safe drugs, a current priority involves operational methods for the distribution of drugs to individuals with moderate to heavy infection and the evaluation of the effectiveness of these measures. In contrast, the geographic distribution is only partially known for leishmaniasis and reasonable incidence information is available for only a few countries. Important issues include - (1) defining criteria for predicting when an outbreak of Kala Azar - as recently occurred in Bihar - is likely; (2) determining the conditions that seem to build up in animal reservoirs or in vector populations prior to an outbreak in humans that might serve as a warning that control measures must be taken, and (3) more complete mapping of the distribution of the disease with knowledge of the host/vector cycles throughout the world.

A particularly important function of epidemiology is that it provides the interface between the basic laboratory sciences and the reality of the field.

Of all the disciplines needed in public health, the plight of epidemiology is perhaps the most severe. Not only are there relatively few well-trained epidemiologists in the Third World, but moreover for those that have completed the training there is a lack of satisfactory career opportunities.

The following foci are amenable and relevant to an expanded Commonwealth programme of scientific cooperation.

1. Development of clinical epidemiology.
2. Epidemiological application of biochemical characterization of parasites.
3. Epidemiological application of serology using well-defined antigens.
4. Development of regional research centres, e.g. Tropical Diseases Research Centre, Ndola, Zambia.
5. Training of epidemiologists.

The time frames appropriate for these iniatives are long-term (5-10 years); they would involve initially training and later collaborative research; participating countries in different regions and subregions of the Commonwealth would gain skilled manpower as well as a capacity to adopt and adapt the new technologies. The infrastructural capacity required could be very variable ranging from individual research scientists to the development of regional research centres.

1. Development of clinical epidemiology

Clinical epidemiology is rapidly acquiring a distinctive domain. The basis for clinical epidemiology is the recognition that the disciplines of epidemiology and biostatistics are as fundamental to clinical medicine as are those of pharmacology and microbiology. In developing countries where the ratio of health problems to health resources is much greater than in technically advanced countries, the need for clinicians to base decisions upon epidemiological principles is even greater than in technically advanced countries. Intensive courses in clinical epidemiology (12 months) are available at McMaster University in Canada, the University of Newcastle in Australia, and are being developed at the Liverpool School of Tropical Medicine. Participants learn the clinical relevance of epidemiological concepts in general and particularly in relation to the protozoal and helminthic diseases as well as acquiring basic skills in research design and analysis. The value of developing a Commonwealth network of clinical epidemiology units needs to be emphasized. Short courses could be conducted in the developing countries to stimulate interest in clinical epidemiology and as a precursor to the establishment of longer courses. Recent experience in developed countries shows that clinicians can be smitten by the epidemiological bug when it is appropriately inoculated in a clinical setting and focussed upon problems of direct clinical interest.

Two features of clinical epidemiology may be of special importance in developing countries. First, it provides an important bridge between clinicians on one side who tend to be hospital bound, and public health epidemiologists on the other side who have become too far removed from patient care. The primary activity of an epidemiologist in a developing country is often that of obtaining reliable data at first hand through the direct examination of patients. Therefore the welding of clinical and epidemiological skills may be particularly appropriate to epidemiological research in developing countries.

2. Epidemiological application of biochemical characterization of parasites.

Of prime interest to tropical medicine is the identification, without recourse to tedious experiments, of parasitic protozoa and helminths that look alike but affect in different ways the well-being of man. Biochemical methods are increasingly becoming of value, and should eventually benefit diagnosis, prophylaxis, epidemiology and taxonomy to the same extent as somewhat simpler methods have contributed to the understanding and control of viral and bacterial diseases. Although perhaps seemingly complex, the newer biochemical approaches for characterization are not different in principle from the immunological methods; whole, or part of, homologous macromolecules are compared between organisms. Indeed as distinguishing molecules come to be recognized by their biochemical attributes, highly specific antibodies may be developed for their detection.

The biochemical identifier would like to recognize the important genes among the complex total genetic code in a parasite; often however genetic information is obtained by examining the proteins produced by these genes among the plethora of such molecules in a cell. Some variations will be peculiar to the individual organism and of little value; others will also exist in related organisms and perhaps be associated with some common behavioural aspect of interest. Already the status of some molecular features is becoming apparent. The applicability of certain techniques to widescale surveys is currently helping the epidemiologist. The experimental methods being used are - 1) DNA Melting Point, 2) Buoyant density, 3) DNA/DNA Hybridization, 4) DNA/RNA Hybridization, 5) Restriction Endonuclease Analysis, and 6) DNA Probes.

The above techniques have been applied to amoebiasis, leishmaniasis, Chagas' disease, African trypanosomiasis, malaria, schistosomiasis, taeniasis, filariasis, trichinosis and paragonimiasis.

The groupings formed on biochemical criteria are now being related to behavioural and epidemiological findings in order to construct sensible taxonomies, even at the expense of discarding ill-founded earlier classifications and nomenclatures. The process is lengthy but finally both the genetic and taxonomic aspects will develop sufficiently to allow a better appreciation of the epidemiological dynamics of the major tropical parasitic diseases, and thus help towards the eventual control of these human burdens.

3. Epidemiological application of serology using well defined antigens

It is generally accepted that sero-epidemiology can be a cost-effective manner of obtaining information on prevalence of parasitic diseases in the Third World. Malarial serology for example can be used, depending upon the particular context, to reinforce data on the point prevalence of malaria but its major use is for the assessment of period prevalence. In particular it can be used to establish endemicity where transmission is stable, to assess changes in transmission, especially valuable following control programmes, and to detect malarious foci following eradication or control activities.

With the advent of the hybridoma technology it is predictable that specificity of immunodiagnostic tests will be improved. Increasing attention is being focussed on detection of circulating or urinary parasite molecules, e.g. exoantigens and released metabolites. Theoretically, quantitative assays for released parasite molecules may give clues on the level of infection. Assays for detection of parasite antigens may also be more responsive to parasite elimination after chemotherapy.

Libraries of monoclonal antibodies to schistosome antigens present in serum; milk or urine of schistosomiasis infected hosts can be expected in the near future as will also be the case for onchocerca volvulus antigens. The two main areas in which such immunodiagnostic techniques have potential importance are in epidemiological studies and in the diagnosis of current or recent parasitic infections.

The new immunodiagnostic techniques that are emerging are weapons which extend the armoury of the expert epidemiologist. Their full exploitation and the interpretation of the results they supply will often require a deep understanding of the many components which combine to mould the epidemiological pattern of protozoal and helminthic infections in a specific locality.

With the rapid advances being made in immunodiagnostic procedures, there is need for training in the performance and interpretation of these tests at both the laboratory and field levels. Much could be gained from courses in diagnostic methods, conducted in institutions or centres of the Commonwealth where the parasitic diseases are endemic and particularly in those in which research in laboratory and field aspects of improved diagnostic methods are in progress, e.g. TDRC, Ndola (see below).

4. Research Centres

Research centres are being established in several countries of the Commonwealth where the protozoal and helminthic diseases are common, e.g. Ndola (Zambia); Accra (Ghana); Nairobi (Kenya), etc. Such countries can provide a venue for collaboration in research and training. An example of such a collaboration can be given in relation to the proposed linkage between the Tropical Diseases Research Centre in Ndola and the two British schools of tropical medicine at Liverpool and London. A description of some of the activities at Ndola and the proposed merger may be used as a prototype of the sort of collaboration that can be established and expanded in the future between various countries in the Commonwealth, with particular reference to field epidemiology, clinical epidemiology and sero-epidemiology.

The epidemiology programme at Ndola has evolved through several phases. When the decision to establish a major Centre devoted to tropical disease research in Zambia was made in 1976, little was known concerning the pattern of disease throughout the country; following a series of rapid disease surveys in several parts of Zambia, three study areas having distinctive ecological characteristics and differing disease patterns were selected for descriptive baseline epidemiological studies. These baseline studies involved multiple disease problems within the population and required a multi-disciplinary approach involving demography, socioeconomic, clinical, parasitological, haematological and ecological studies.

The objectives of these studies were:

1. To establish disease patterns in ecologically diverse areas of the country particularly so as to provide basic information needed by the Ministry of Health for planning and evaluation of the disease control programmes.

2. To obtain baseline and background data for intervention trials and studies to determine risk factors concerned with malaria, schistosomiasis, trypanosomiasis and other important diseases. Several such studies are described below following the reports on the results from the baseline studies.

3. To provide essential information concerning the interaction of the specific diseases with each other and with other factors within the population to identify those that might be of importance in the undertaking of disease control measures.

The following were the main results from these baseline studies:

(a) Baseline studies - The Kampumbu Study Area

The first descriptive, baseline study in the Kampumbu area was carried out in mid-1979 on a sample of 1,341 individuals living in eight villages in the upper Lwanga Valley selected from about 154 villages having a total population of about 10,000. The study included data on demographic variables, social and economic status, medical history and physical examination findings, laboratory investigations of haematological and biochemical values, and of parasitological and bacteriological infections. The major results can be summarized as follows:-

1. Census profile - Very young population with a median age of 13.1 years. A relative deficiency of young men (ages 15-44) as a result of their seeking employment in the copper belt area. Estimated infant mortality was 236/1,000 and the cumulative mortality was over 350/1000 by the age of 5.

2. Socioeconomic status - Subsistence agriculture was the predominant activity supplemented by some families with a limited amount of hunting and occasional fishing. No major cash crops were grown. Five ethnic groups. Literacy of men over 20 years old was 28%; virtually no women were literate. 60% of under 15s were registered in primary school.

3. Nutritional status - 65% of the under 5s were undernourished weight for age by Gomez class I and 10% were severely malnourished, Gomez class III. Thus there is a very substantial amount of protein-energy malnutrition. Further, 17% percent of children under age 15 were anaemic (micro hematocrits (PCV) under 30%) and 9% percent of women ages 15-44 were also.

4. Malaria - The area could be classed as hyper to holoendemic with a spleen rate of over 50% and a parasitaemia of over 70% in the under 10s. Adults continue to have splenomegaly, but the area is also endemic for S. mansoni. P. falciparum is the predominant parasite, but there is a substantial proportion infected with P. malariae and P. ovale. Infection with multiple malaria species is associated with splenomegaly of Hacketts 3+ and over.

5. Schistosomiasis - Overall prevalence of S. mansoni is 50% with 70% of the age 10-14 infected. 23% of this age group have egg counts of over 500 eggs per gram.

7. Hookworm - Overall prevalence of hookworm was 30% with 45% of those ages 5-14 infected, but the intensity was not sufficient, apparently, to contribute importantly to the anaemia indicated above.

8. Trypanosoma brucei rhodesiense - Four individuals, previously undiagnosed, were found with parasitaemia due to T.b.rhodesiense during this survey giving a prevalence of about 1/2 percent, consistent with at least 10 new cases a year from this population, i.e. an incidence of about 10/1,000 per year - a very substantial public health problem indicating that over an average life span of about 50 years half the population would develop clinical sleeping sickness which is fatal if not treated. See below about further studies.

9. Multiple infections - Most of the population had multiple infection, e.g. malaria, S. mansoni, hookworm. Observations that may be useful to investigate further include the following: individuals infected with P. falciparum were about 20 times more likely to be infected with P. malariae than those uninfected with P. falciparum (age-standardized) and about twice as likely with P. ovale. Also individuals infected with S. mansoni had a significantly lower rate of infection with malaria and a lower parasitaemia than those without S. mansoni.

(b) Baseline studies -The Kabinga Study Area

A similar baseline study was conducted in the Kabinga area near Lake Bangweulu where the characteristics of the ecology and of its population are different in a number of ways from those of the Kampumbu area. Fishing rather than subsistence farming was the most important occupational activity of the men. There was substantially less evidence for malnutrition probably because

of the availability of fish. Malaria parasitaemia rates were somewhat lower and no P. ovale was found. There is no human trypanosomiasis in the area. S. haematobium prevalence ranged from virtually zero to near 60% amongst the 11 villages selected for the study and this rather than S. mansoni was the predominant form of schistosomiasis. Hookworm infection was much more common, but there was no greater level of anaemia.

Taken together, the results confirm the high level of multiple diseases in rural Zambia, but demonstrate major variations in the patterns of disease in populations living in differing ecological settings and having differing ways of life.

(c) Epidemiological studies on T.b. rhodesiense

Following the baseline studies, further investigations concerned with trypanosomiasis were carried out starting in 1980. The overall objective was to develop a more effective strategy for trypanosomiasis control for the country. Specific studies were as follows:

1. In conjunction with the SWG on Trypanosomiasis data from the baseline studies were combined with data gathered from local hospitals in the area to obtain information on all patients diagnosed with human trypanosomiasis since 1980 in the Chibale-Kampumbu areas. House-to-house mapping was carried out and time-space analysis of the cases was looked at to determine the stability over time of geographic clusters of human trypanosomiasis in the area. The SWG on Trypanosomiasis was primarily concerned with investigations of the ecology, the tse tse fly and animal reservoir studies. The principal reason for these studies was the isolation, identification and characterization of the trypanosome parasites by means of blood incubation infectivity test and isoenzyme techniques. The long term goal is to obtain the essential information necessary for the prediction and avoidance of the periodic epidemic outbreaks of human trypanosomiasis in the area.

2. In direct relation to these studies a prevalence (cross-sectional) study was carried out in the Chibale/Kampumbu area with the following objectives:

(a) To detect sub-clinical cases of trypanosomiasis in humans to determine if such might be important as a possible source of acquired resistance to T.b. rhodesiense or as a reservoir of infection for transmission to others. If there were such sub-clinical infections, isolation of the strains should enable identification as to whether these were due to T.b. rhodesiense or to some other related species.

(b) To compare various diagnostic methods including wet film, stained thick film, Woo, anion exchange column, rodent inoculation and immunofluorescent antibody techniques.

During this study in which 1,056 individuals were examined, six as yet undiagnosed cases (0.55% prevalence)were detected ranging in age from 8 to 55 years. Though they were not ill enough to have sought treatment, all had symptoms. Another four individuals from neighbouring villages, though not part of the sample villages selected for the study, reported during this time to the clinic and were found to have trypanosomiasis. Conclusions were that truly subclinical cases with parasitaemia were not common; but again about 1/2 percent of the population had parasitaemia who had not yet sought treatment. Whether this continuing prevalence of parasitaemia in the

community constitutes an important reservoir must be clarified, but certainly this remains a distinct possibility. The fact that a substantial number of those previously undiagnosed are women and children increases the likelihood that infection was acquired near the household. Following this study 12 cases in one village (Kasyasya) of 76 population were found in one year. This village has been known to have perenially a high percent of cases and is presently under detailed investigation.

No single diagnostic test was clearly superior in this small group of patients but of those that demonstrated parasites rodent inoculation and the mini-anion exchange column were apparently able to detect lower levels of parasitaemia than the others.

3. Important additional studies involved the follow-up of those who had positive IFA tests but had no evidence of parasitaemia and the follow-up of those who had had more than one clinical episode of trypanosomiasis. In the eighteen months follow-up to date, two out of sixty of those who had 2+ or greater IFA positive have developed clinical trypanosomiasis suggesting that they are at higher risk than those who had negative IFAs. Of particular importance is that five people gave a documented history by hospital records of recurring trypanosomiasis. The question is whether these were flare-ups of their previous infection, suppressed perhaps by inadequate chemotherapy, or whether they were genuinely new infections. The evidence would seem that several were new infections because of the long period of time (more than two years) between episodes. Until there are better markers for strains of T.b. rhodesiense, however, a definite answer cannot be given. In any case, people who have once had clinical disease are at greater risk of getting it again; further, there is no evidence that an acquired resistance to the disease occurs.

4. Anecdotal information and some indirect evidence pointed to the possibility that long time residents in the area were less likely to acquire T.b. rhodesiense than were newcomers. A case control study was carried out specifically to investigate the hypothesis that those born and raised in the endemic area had some degree of protection as compared to those who moved to the area. Patients with trypanosomiasis were compared to controls, both hospital patient controls and nearest neighbour controls, as to their place of birth and duration of residence in non-endemic areas; no difference was found. The study has demonstrated that long-time residents were at equal risk of acquiring the disease as those who had recently moved to the area from areas not endemic for trypanosomiasis. At present, an analysis of the clinical characteristics is being undertaken to see if the migrants had a more acute or severe form of the disease.

(d) Community trial of anti-schistosomiasis drugs

In order to reduce the effects of the high level of Schistosoma mansoni infection in Kampumbu, a community trial of praziquantel was started in May 1982. In keeping with the new strategy of schistosomiasis control as recommended by PDP, the overall goal of this approach was to reduce the worm burden in humans by the use of chemotherapy thereby minimizing the resulting pathology, morbidity and mortality rather than concentrating on the reduction of transmission per se. In this approach, the emphasis is on disease control rather than on infection control.

The specific objectives of the study are:

1. To determine the optimum frequency (spacing) of praziquantel.

2. To determine the most suitable method for community distribution of the drug.

As indicated above, the prevalence of S. mansoni in Kampumbu was over 70% in the 5-14 year age group (over 50% for the population as a whole) with high intensity of infection in this age group as well. Quantitative S. mansoni egg counts of stool specimens (Kato technique) were carried out on the entire population; all who were found positive were treated with praziquantel.

Re-examination of stool specimens were carried out at three monthly intervals thereafter for the first year with treatment of any one positive each time. At the first follow-up in September/October 1982, the prevalence had been reduced to 34% and, more important, the total egg count in the population had been reduced by 70%.

By the end of the first year, it should be possible to determine the rate of reinfection and the time required for a return to moderate to high intensities of egg counts. During the first phase of the study, the drugs have been distributed by the TDRC field team, but appropriate ways for the drugs to be distributed via the schools or community leaders are now being explored. The Ministry of Health has been involved in the planning of the project and depending upon the effectiveness and projected costs that may be involved when such an approach is fully worked out, the Ministry of Health will base its S. mansoni control programme on these findings. A protocol for community participation and costing for the distribution of the drugs is in preparation.

Role of Liverpool and London Schools

A 'draft' agreement between the two schools and TDRC Ndola is being worked out whereby the schools would actively collaborate (1) in the scientific direction of the centre; (2) would help to train Zambian staff members in the various aspects of parasitic diseases investigation; (3) would second its own staff members for variable periods of time to embark on collaborative research projects at the clinical, field as well as laboratory levels; (4) part of the funding would be provided by WHO via the appropriate authorities in Zambia.

This type of venture could provide the prototype for similar co-operation among other institutions in the Commonwealth providing funds become available from other sources.

5. Epidemiological training

there is an urgent need for increasing the pool of epidermological talent for strengthening disease control programmes and the research and evaluation that they require. The TDRC Ndola for example is being used to train post-doctorate fellows in field epidermological techniques.

In order to attract and retain able professionals, satisfying careers that are competitive with other sectors must be established. If epidemiologists receive a lower income and status than their colleagues in other fields, few individuals can be expected to make the personal sacrifice needed.

EPIDEMIOLOGY

Professor G Rose

London School of Hygiene and Tropical Medicine

The kind of expanded programme which the Expert Group is considering would be highly relevant to this School, and in particular to our Tropical Epidemiology Unit.

1. Priority Topic Areas

   (a) Study of emerging patterns of non-communicable disease (e g cardiovascular disease; new patterns of cancers, particularly of lung and breast; other "diseases of development").

   (b) Occupational health (a serious problem where there is early industrialisation without adequate control of working conditions or occupational health services.)

   (c) Many of the newly developed interventions against tropical diseases (e g, schistosomal drugs, leprosy and malaria vaccines) are very close to the stage of requiring large scale field testing. One of the consequences to the shortage of trained epidemiologists in less developed countries is a critical lack of persons experienced in the field trial methodology. This may impede the proper and efficient assessment of new interventions.

2. Modalities

   (a) Training
   - Staff exchanges
   - MSc/PhD students
   - Regional workshops on specific issues
   - Intensive courses in appropriate methodology put on 'ad hoc' at LSHTM.

   (b) Collaborative research
   - based on institutional links
   - Growing out of training activities

   (c) Information exchanges
   - Consultant visits to developing countries
   - Visits to developed country institutions by developing country workers

We already possess the necessary back-up of people and skills for such activities, and would be willing to submit a more detailed proposal on any specific aspect of them.

Scientific and Technical Information Transfer in Developing Countries with special reference to Agriculture

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1. Users of Agricultural Information

Three user groups may be distinguished:

- scientists
- planners and developers
- extension workers, farmers, traders.

Scientists want to know how research was done, what results were and what the conclusions were. They want to be able to judge for themselves the reliability of the work. They often need to refer to the original research for information on matters of minute detail.

Planners and developers do not have the time for all that. They need briefing documents, a survey of the salient facts, which enables them to evaluate options or possible lines of action.

Extension workers, etc. need clear directives: 'do this' or 'do that' according to circumstances, and a range of statistical or factual data on production, markets, etc. etc.

2. Accessibility of Information

Scientists are potentially well supplied with information. All the information tools they need are available: primary journals, conference proceedings, books, reviews, newsletters, abstract journals printed or in machine-readable form, and document delivery (photocopy) services. But scientists may not use this knowledge base to its full potential for two reasons: funds are lacking or the value of information is not recognised.

Planners and developers have to take decisions. Often these are taken on the basis of inadequate information. Planners and developers can rarely use scientific literature in its original form; they need, for example, a review of options based on an objective assessment of scientific findings, statistical data, socio-economic data and so on, laced with a good measure of common sense. This 'consolidated' information has to be prepared to meet each particular situation.

Extension workers, farmers etc. need to know what to do. They need recommendations for action. Again, this consolidated information needs careful preparation for it to be accessible and effective.

In brief, scientific information is readily available to those who seek it, but it is all too often not applied by those responsible for development and production. It is in the application of knowledge that modern information systems seem to break down.

3. Modern Trends in Information Systems

If you go to one of the large on-line exhibitions in London or New York, you may be forgiven for thinking that printed books and journals have been abolished. Yet the printed word remains one of the most effective and flexible ways of conveying information. Despite the push from technology, printed books and journals will remain with us for the foreseeable future. On-line searching is largely the prerogative of industry, while academics are still hooked onto journals. Database producers, in order to survive, will undoubtedly set prices in such a way that, while on-line/tape revenues are maximised, there will be every incentive to continue journal subscriptions. Economic factors will therefore modify the effect of technology push.

4. Ways in which Scientists may be Helped

(a) Education

Scientists need to be taught the value of information. This should be a compulsory section of every undergraduate and graduate course; it needs to be learnt even earlier, at secondary school. Short courses (two to three weeks) for practising scientists (and agriculturalists) should also be encouraged.

(b) Model Library

Libraries are moving from their role as depositories of printed matter to a new and challenging role - that of information centre. The World Bank is, I understand, to sponsor a project at the Agricultural University of Beijing to establish a new-style library making full use of conventional and new information systems. This could well be emulated elsewhere.

(c) Funds

(i) for journal subscriptions and document delivery. This is the scientists' greatest need. All librarians are having to cut subscriptions, largely because funds are inadequate. Well-endowed libraries are having to cut back, while journal subscriptions in some developing country libraries other than those payable in local currency, are almost unknown.

(ii) for machine-readable services (capital and running expenditure). Some libraries, eg at the International Livestock Center for Africa, run in-house cataloguing and SDI+ on minicomputers. User scientists recognise the value of this comprehensive and immediate service. Such initiatives could be emulated widely; again, funds are the limiting factor. Funds are needed for hardware*, software*, leasing databases, running costs. New facilities for downloading from on-line vendors and provision of SDI on floppies point to the growing role of microcomputers in information processing.

5. Conclusion

While new technology offers exciting possibilities for information processing for scientists, it is not the whole answer. It should be encouraged and supported where the likely level of use and the general awareness of the value of information warrant it in economic terms. More importantly, for scientists, ways must be found of providing printed journals≠. But the greatest need of all lies in the provision of consolidated information for development.

Footnotes

+ The ILCA runs its SDI service on CAB and AGRIS tapes.

* In a paper of this nature, it is not possible to comment on particular hardware or software; indeed, it is beyond my competence to do so. But it is worth noting that CAB has a powerful and flexible processing system, running on Digital minicomputers, which comprises four main elements: data entry (a very flexible system that can be run separately on DEC microcomputers), and interface programs (GFMS) to data management (BASIS) and typesetting (COMPUSET). Digital equipment is available and supported world-wide. The CAB system can provide information on floppy disc which can be accessed on several types of microcomputer, as well as on tape.

≠ The International Maize and Wheat Improvement Center is paying for 500 subscriptions of Wheat, Barley and Triticale Abstracts for scientists in developing countries. The CIMMYT DG said 'We have 500 scientists out there who need this information'.

Information Technology and Communications for the Advancement and Promotion of Science

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Introduction

This paper is concerned with Information Technology not as a science, but as a tool for science. It is considered in the same sense as would be a weighing balance, a microscope, or a spectrometer.

Information Technology, in the form of communications and in the form of computers has been with us for some years, but it is only with the convergence of communications and computers made possible by the developments in the microchip industry, that IT has been recognised as a major force for enhancing the worlds economic and soical development.

It is recognised that IT poses both dangers and possibilities for developing countries. The dangers lie in the possibilities of IT widening the economic and social differences between industrialised and non-industrialised countries. The possibilities lie in the improvement of inter-country communications, with the consequent possibilities for improvement in trade, and in the replacement of industrial skills, scarce in the Third World, by automated operations.

The possible uses of the technologies are many, both as service to all fields of science, and in particular fields. It is only intended to mention a few, to indicate the scope.

Analysis & Interpretation

2. For the foreseeable future, the major activities of the Council will centre around the establishment of maintenance of scientific networks, that is the formation of groups of scientists with similar professional interests and assistance to the groups by means of information exchange, fellowships, exchanges of scientists, seminars and workshops.

   Within this concept, at least three aspects of IT are likely to be of importance:

   (i) Compilation and use of data banks

   (ii) Communications, and

   (iii) IT as it affects how and where the 'mechanics' of science are performed, ie how are values measured, quantities counted, and so on.

2.1 Compilation and Use of Data Banks

A major constraint to the development of science in the Third World is the difficulty of access to up-to-date ideas and literature. Not only are scientists, through lack of funds, unable to gain access to relevant

literature, but neither through the problems of distance, are they able to track what literature is available.

Networks can provide solutions to this problem, provided they have access, at some point in the network, to computerised data banks. In general, it will be the function of the Secretariat to provide such access, though there is no reason why data banks should not be accessed at any available point.

Modern communications, of course, does render fairly irrelevant where the data bank is in relation to the access point, and in the normal time frame of scientific research, the postal time between access points and network members is not significant. It may be foreseen, however, that at some point in the future electronic mailing will become widespread, thus reducing or even eliminating paper postage.

2.2 Communications

Historically, long-range communication has paralleled developments in technology. One may perhaps, highlight the wheel, the steamship, the train and the aeroplane as important mechanisms for long range communication. But the advent of telecommunications is the event which has made possible instant long range communication. The advent of microprocessors has made this instancy convenient. What is foreseen in the immediate future, if not in actual existence, are possibilities of satellite-relayed massive digitized data streams, which form the carriers for teleconferencing, data transmission, and the like.

In terms of Commonwealth Science, this would appear to benefit the networking concept. Not only would scientists in the more remote areas have instant access to colleagues, but it may be arranged that they may have instant access to equipment. The certainties of scientists having to do without expensive equipment or having to do with second best are now replaced by the possibilities of centralisation of facilities. Such facilities need not be centralised in the established scientific heartlands.

Thus, given that several network members may need a large computer, it may be placed anywhere in the network, provided the infrastructural requirements can be met. One paper even mentions the possibility of a 'Commonwealth' computer. Such a concept, worldwide or regional, may also be applied to other expensive equipment.

IT Affecting the 'Mechanics' of Science

2.3.1 There is hardly any scientific activity whose performance has not been modified to some extent by the microchip. In many cases the modifications have resulted in the lowering of the skill levels required to perform the activity. Meteorological observers now may be relieved of measuring daily rainfall using a glass measuring jar: rainfall can now be measured and recorded digitally for periods of up to three months, enabling the observer to make only infrequent visits to the station, and 'stepping through' the memory to obtain daily values.

The implications are that scientific skill requirements are continually being modified. In one sense, this brings requirements for retraining, in another, it allows developing countries to leapfrog over traditional skills, and adapt to the newer and generally simpler methods.

2.3.2 Microelectronics not only affects how scientific activities are performed, it affects where. The so-called 'barefoot' microprocessor, ie microprocessor based equipment which can be taken into difficult environmental conditions, is with us. Laboratory based techniques can now be replaced by field based techniques. In order to determine soil moisture, it is no longer necessary to bring soil samples to the laboratory, soil moisture can be measured in situ using electronic equipment. Thus, in the sense that much of the developing world's science is aimed at the rural sector, the possibilities of taking science into the field is a significant development.

Conclusions

3. Clearly, IT and communications will pervade all aspects of science in the Commonwealth. It may provide great benefits for the developing Commonwealth in terms of access to information, speedy communications, centralisation of equipment coupled with dispersion of personnel, which is capable of withstanding the difficult environmental conditions found in the Tropics.

IT and communications therefore strengthen the network concept under which the CSC operates. The matrix of future programme areas becomes more logical in that the 'low' programme areas - IT, microelectronics, Remote Sensing, etc. are enmeshed with the 'what' and 'why' programme areas - Mineral Resources, Aquaculture and Agroforestry.

POPULARISATION OF SCIENCE IN THE DEVELOPING COMMONWEALTH

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1. Introduction

Science, together with its practical alter ego, technology, have made possible man's improved standard of living. In particular, the scientist, through application of science, has created technologies not only to protect Man against nature's ravishes but generally to enhance science's benelovent intent in society. The sequel has been that process diffusion of science in society, generally concomitant with process acculturation of technology, has been invariably marred by the naivety of mechanisms:

- to render scientists aware of the impact of science in society;
- to render society aware of the scientific components of social problems;
- to endow the public with an enhanced understanding of science for application to decision-making in industry and government, policy-formulation in national science and technology policies, management of the environment and analysis of technological advances;
- to endow the public with an enhanced understanding of science to facilitate interpretation of natural as well as ethno-cultural phenomena; and
- to inculcate into society's socio-cultural substratum an enhanced degree of affective interactiveness to objectivity of scientific analysis and evidence, the scientific method and the role of science and technology in society.

In its broadest sense, popularisation of science implies an ultimate evolution into a scientific knowledge-based society (SKBS). Generally, this is yet embroyonic, at least with respect to the developing countries. Three aspects among possible others, warrant due consideration, however, namely, the popularisation of science through the expedience of:

- public awareness in science
- public understanding of science; and
- attitudinal profundity to science.

2. A Raison d'etre for Popularisation of Science

Many countries comprise of socio-economic milieu that are pervaded, to varying degrees, by effluents of technological breakthroughs in home appliances, automobiles and communication systems. Pertinent lifestyles subsequently become increasingly prone to characteristic modes of thought and values that inevitably call for the infusion of affective rationality to science and technology. That public attitude to science can be various, diametrical and even dialectical may be evident from a number of observations:

(a) To a portion of society, investigation or formal pedagogy in science right up to the frontiers of professional practice gives the impression that scientific knowledge is irrevocably true in character, all embracing in scope an uniquely valuable to mankind. Here society, through the possession of an insufficient knowledge-datum on the nature of science and the scientific method seems to view science as a dogmatic characterised by impeccable truth.

(b) To another portion of society, science is that which imposes folly differentials on contemporary society. Here the public through extraneous influence, seems to have either a purblindness in respect of the potentialities of science to solve problems in society or views science as a major source of world problematique.

(c) To a portion of the scientific community, a proportion of teachers of science and researchers in fundamental research, science is strictly academic science and research in science is strictly pure research, any deviations from this set idea being branded as next to "sheer prometheanism." Here scientists, who constitute a portion of society, seem to continue to cling to the inertia of tradition, that of keeping science well divorced from pertinent social contexts.

Popularisation of science in respect of public awareness and/or public understanding of science is inevitable in both the developed and developing countries for reasons that are various and varied, amongst which the following may be singled out:

- R & D in science gains sustenance through the aegis of public funding, popularisation of science is inevitable here for the purpose of an effective scientist/public rapport;

- scientists derive from amongst members of the public's rising generation; popularisation of science is one way of rousing a spark of interest in the neophyte, the future scientist;

- scientists are an integral part of a country's socio-cultural whole: popularisation of science should assist science becoming part of a country's socio-cultural heritage within the generally universal character of science;

- advances in science and technology are phenomenally apace for both the scientist and the layman, however, differentially: popularisation of science should assist not only the public at large but equally scientists engaged in specialised fields of pursuit, for the purpose of generating general awareness in the multitudes of rapidly advancing fields of science.

3. Public Awareness-cum-Public Understanding of Science

The degree to which science and technology interacts with society depends upon the extent of diffusion of science and acculturation of technology into society's knowledge-base. Free diffusion of science and free acculturation of technology in society are, in general, quasi-dynamic in character. The making of a scientific knowledge-based society should be the ultimate goal. However, Popularisation of Science as a mechanism for enhancing public awareness-cum-public understanding of science should offer a modest effort aimed at activities:

- to cause science to be generally known;
- to extend knowledge of science to the common people;
- to present science in a popular form.

Science as a topical experience is "science for the citizen" (or is it "science for the million"?). Modalities for popularisation of science in the context of "science for the citizen" are open to options whose choices depend, to some extent, on country-specific criteria for their successful implementation. A selection from some or all of the following activities are deemed expedient for serious consideration relating to mechanisms for popularisation of science:

Use of Mass Media and Information Services

This could cater mainly for the urban community where radio, TV or newspaper constitute basic media for information dissemination on popular science. Immediate needs perceived here would include the availability of journalists with broad-base scientific background. Moreover, the general public would need to be encouraged to attend to science programmes on radio and TV and to read regularly, science columns in newspapers. Science on radio, TV, or newspaper is a novel inclusion for many developing countries.

Popular Science Publications

Popular science writing in many developing countries needs recognition, specifically by publishers of educational books. Apparently, publishers have done little in the past history of a number of developing countries to encourage indigenous efforts in the writing of science books. Moreover, popular science writing calls for commitment from the traditional scientific community.

Organising of School Science Expos

This is one way of popularising science through the activities of school science students culminating into possible periodic (annual) national science fairs. Target groups range from school pupils to the general public.

Establishment of Scientific Professional Bodies

This could take the form of learned societies, academies of science and technology or associations for the promotion and advancement of science and technology.

Establishment of Science and Technology Centres, Science Museums and Science Libraries

This could help popularise science from several perspectives:

- evolution of science in a historical perspective;
- science presented in popular literature;
- display of physical models in modern science and technology.

Video Cassettes/Synchronised Slide Films/Movie 16mm Films

These could be made on salient aspects of popular science to suit various target groups ranging from school pupils through policy makers and the general public.

4. The Pedagogical Dimension

Science as an empirical experience is "science for the inquiring mind". It is an aspect of science enhanced through the heuristics of formal science pedagogy and/or the rigour of formal scientific research. The goals, scope and methodology of empirical science are moreover characterised by a degree of academicism which is unpalatable for general public assimilation. Infusion into the formal education system of broad-based science curricula characterised by parsimonious selections of topics pertinent to science, technology and society (STS) could assist enhancing multiplier potentialities in relation to attitude shaping towards science as a mode of thought that is not compartmentalised.

Course curricula pertinent to popularisation of science pedagogy could be developed with aims that broadly seek:

- to foster an understanding of the nature, potentiality and limitations of scientific knowledge;
- to enhance the appreciation that the utilitarian aspect of scientific knowledge, as rendered manifest through application of technology, can be both beneficial and detrimental to society; and
- to promote a realistic portrayal of the scientist and the scientific method.

Depending on the level of pertinent formal education, however, topics could broadly incorporate areas such as the following:

(i) the Scientific Method

(ii) Integrated Energy Studies

(iii) Renewable Natural Resources

(iv) Environmental Science and Education

(v) Selected physics-based, chemistry-based and biology-based technologies.

In selecting specific curricular topics of the type mentioned above a number of points would need to be borne in mind, such as:

(i) the relevance of the topics to country-specific endogenous settings;

(ii) the appropriateness of the topics vis-a-vis specific levels of formal education; and

(iii) placement of focus for the younger pupils on local issues, for the older on global issues.

4. Conclusion

The path to a scientific knowledge-based society is not without impasses. Constraints exist which pertain to a number of factors, such as the following:

- the proportion of population with threshold potential to assimilate science-based knowledge;

- the degree of exposure to scientific and technological innovations; and

- the degree of ease to diffusion of exogenous-based as well as endogenous-based science into a country's socio-cultural substratum.

The need is compelling enough, however, for popularisation of science to take root in the substratum of public knowledge. An adequate public perception of science is as important to the scientist as to society in general, including the policy makers. For ultimately it may determine, in a positive mode, the course of science vis-a-vis the framework of a country's general development planning. Efforts need to be pooled at individual and institutional levels to render feasible the modalities to popularise science. Commonwealth Science Council (CSC) conjointly with Commonwealth Secretariat's Education Programme could, through organisation of workshops involving scientists, educators and science communicators attempt developing a better awareness of the need for various modes of popularising science. Commonwealth Science Council could also inject pertinent inputs into the activities of the Commonwealth Association of Science, Technology and Mathematics Educators (CASTME), which was born out of the need to assist Commonwealth educationalists to promote the mutual interaction of science, technology, mathematics; CASTME activities culminate into annual CASTME awards for contributory excellence in school science/mathematics in relation to society. The Guiness Award for Scientific Achievement in the Service of the Community (GASA) is yet another annual presentation which aims to promote excellence in science in the Commonwealth for the cause of humanity. Further afield, Commonwealth Science Council's collaboration with UNESCO and the Association of Commonwealth Universities (ACU) could be expedient. UNESCO-sponsored seminars on the popularisation of science and technology have been held in Lusaka (November 1971) and Nairobi (December 1983). UNESCO presents, each year the Kalinga Prize for the Popularisation of Science, to any person with a distinguished career of service in the interpretation of science and research to the public. Commonwealth Science Council's participation in UNESCO activities of the type cited could help enhance the subject of popularisation of science amongst member countries of the Commonwealth.

THE TEACHING OF SCIENCE AT SECONDARY AND TERTIARY LEVELS IN THE DEVELOPING COMMONWEALTH

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1. Introduction

The period 1965 - 1980 was characterised by a growing awareness among developing countries that results of educational research do have applications in areas pertinent to:

- curriculum development, revision and innovation in science;
- methods of teaching of science at all levels of school education;
- attitude development for science;
- skills development in science; and
- cognitive development in science.

A variety of curriculum development projects thus appeared on the educational scene, each with:

- different degrees of emphasis on both the cognitive and affective components of the structure of the disciplines of science knowledge; and
- basic focus on discipline structure, key concepts, generalisations, hypotheses, models and theories.

Curriculum developers advocated various methods of instructional strategy, with predominance of combinations of 'limited exposition' and 'guided heuristics' for both classroom pedagogy and laboratory investigation. Textbooks predominantly presented subject content inductively (rather than deductively) in order to match the pertinent heuristicism of instructional methodology.

Education is inevitably concerned with change in society. Science teaching should imply education to acquire scientific capability for development. A number of factors have rendered this possible but only differentially and with constraints of various origins, mainly related to:

- traditional socio-cultural pressures bearing upon curricula;
- the nature of the training of teachers of science; and
- the trend of availability of science teaching equipment for the experimental method.

These factors pose a dominant challenge to any objectives by developing countries to effect education for the acquisition of local scientific capability for development.

2. The Curriculum Problem

(a) Formative Ideas of New Curriculum: Rationale

The teaching of science/mathematics at school and tertiary levels has been a priority matter for concerted effort amongst countries of the developing world since the conception in 1971 of UN's World Plan of Action for application of Science and Technology to Development. During the last decade and a half or so the task of course and programme design in many developing countries of the Commonwealth has endeavoured to produce a varied and inter-related set of learning experiences in conformity with latest findings of science and mathematics education. For the first time or so:

- operationally stated terminal objectives constituted prototype statements of the objectives of a science or mathematics syllabus;
- existing knowledge about processes of absorption of science and mathematics material in various kinds of learning situations were invoked; and
- characteristics of procedures and materials used in evaluating pupil/student achievement (formative, summative, etc) were attempted.

The move to endow science/mathematics pedagogy with these aspects of science/mathematics education inevitably materialised at the realisation that typical of any basic goals of education in society, the objectives of any science/mathematics curriculum are envisaged to meet:

- the needs of the learner (personal goals)
- the needs of the society (utilitarian values and socio-cultural values)
- the needs of the discipline (intrinsic and/or aesthetic values)

(b) Secondary Science Curricula

The ethos of education in many developing countries is one that has been acquired as a socio-cultural heritage from the colonial era. In particular, many school science programmes in countries of the developing Commonwealth evolved as adaptations of school science programmes originating from the US and the UK, amongst which were the Physical Science Study Committee (PSSC) and the various Nuffield Science Projects in physics, chemistry, biology and physical science. In East Africa, for example, the East African Secondary Science Project (SSP) emerged as an adaptive programme of the Nuffield Science projects for the years 1, 2, 3 and 4. In the Commonwealth Caribbean a number of projects, characteristically of the integrated science type, included WISCIP, MONA, WISC and SDSP for use in the years 1, 2 and 3 and CARISO for use in the years 4 and 5. A characteristic feature of these science programmes was to present science as an experience in investigation and discovery. Hence the requirement that concomitant pedagogical instruction flourished under free or guided heuristics. An additional trait was the endeavour, in many of the curricula, to present science as integrated science rather than traditionally discipline-based.

Because of various attempts to render curricula in school mathematics relevant to science at various levels, a brief resume on the nature of secondary mathematics curricula will be expedient.

(c) Secondary Mathematics Curricula

Contemporary view of mathematics education portrays mathematics as a discipline with complementary dual existence, namely:

- mathematics as a 'body of knowledge'; and
- mathematics as a 'mode of thought'.

It was an attempt to realise this dual existence of mathematics that necessitated a revolution that came to be described by the epithets 'new', 'modern' or 'contemporary'. The 'new' mathematics, originating in Europe and the United States may be characterised by its goals, its content and its instructional methods. Fundamental objectives of the 'new', 'modern' or 'contemporary' mathematics programme included:

- modernisation and diversification of mathematics content at all levels of school curriculum; and
- pedagogical reform in teaching of mathematics at all school levels.

Adaptive transfers of mathematics curricula gave rise to several 'school mathematics projects' in many of the developing countries of the Commonwealth. In East Africa, 'the School Mathematics of East Africa' for pupils in the years 1 - 4 was an outgrowth of UK's School Mathematics Project (SMP) while the 'Kenya Advanced Mathematics Project' (KAMP) was a direct adaptation of UK's 'SMP Advanced Level'. Under the new-style programmes, secondary school mathematics curricula became informal-intuitive, physical-informal, non-axiomatic and less discipline-based. Secondary mathematics content became typified by set-theoretic phraseology and symbolism, matrices, transformation geometry, vectors, topology, statistics and probability. Presentation became predominantly inductive and less formalised while didactical pedagogy became authoritarian-free and more heuristic. This, it was argued, was in concordance with a major goal of the 'new' mathematics revolution which set out to make mathematics more exciting and enjoyable while imparting a knowledge of the nature of mathematics.

3. Present Status of Curriculum Programme

A dialectical conflict among curriculum innovators and policy makers has nevertheless evolved during the past half a decade or so, mainly at the realisation that:

- a content item pertinent to an industrial society may be completely ersatz and irrelevant to a country with a characteristically agrarian setting: the majority of countries of the developing Commonwealth are typically agrarian; and
- a country can admit particular methods by which instruction is to be given only within the constraints exerted by the financial budget and manpower availability of the country.

In particular, attempts to implant the attitude of treating science as an empirical experience in investigation and discovery have, to varying degrees of magnitude, been marred by a number of attendant factors:

- lack or absence of teachers specially trained in the pertinent heuristics of science pedagory;
- continued inertia of tradition, of teachers; to continue to practise the authoritarian mode of instructional pedagogy;

- expensive outlays in equipment, which had to be imported from overseas;

- deficiency or inadequacy of teacher dexterity to improvise simple/ basic experimental appartus for empirical investigation by pupils; and

- lack or absence of a country's national science policy to effect an integrative guidance for the trend of progress of science education within the country.

In mathematics criticisms of the 'new' style programme have observationally centred on:

- the risk posed by the pupils tendency to prioritise symbolism at the expense of conceptual insight;

- the risk to resort to rote learning in attempts to gain mastery of phraseology and symbolism; and

- the risk to equate the pupil's use of symbols correctly with an understanding of the notions and concomitant relationships.

Moreover:

- parents have continually complained of their children's apparent numerate or manipulative illiteracy;

- science teachers have felt, to some extent, that the new style programmes in secondary mathematics have not been very supportive to science, and

- curriculum revisionists have felt, to some extent, that vocabulary in the various 'new' mathematics curricula has been rather unworkable to the pupils.

The development of the new curricula for secondary science and mathematics teaching which has characterised the last one and half decade or so has begun to give way to alternative curricula. India, which had introduced PSSC without due consideration of certain conditions such as motivation and re-orientation of teachers, has now re-modelled its science curricula to suit local conditions. In East Africa, the SSP has given way to science curricula modelled between the traditional and the SSP, while SMEA has similarly yielded to a moderno-traditional trait.

Several countries including Malawi and Nigeria which had introduced 'new' mathematics on a limited scale, with an exercise of caution about its expansion, have withdrawn in favour of traditionally-oriented curricula.

4. Implications for Curriculm Revision

The curriculum and organisation of secondary schools in many developing countries are often based on the assumption that the sole, or main, function of secondary education is to prepare pupils for university entry. Admittedly, it is from secondary schools that the bulk of supply of university trained scientists and technologists are normally drawn. Plausibly, it is also from this group that the bulk of future skilled manpower and sub-professional or vocationally trained technicians emanate. Recalling that a majority of

secondary school curricula in science and mathematics are probably too much influenced by the quite different requirements of the more developed countries in both course content and teaching methods, there is a need for the re-design of secondary education as a comprehensive and terminal point with emphasis on science and mathematics as essential elements in sound basic training as well as the acquisition of adaptability to different future skill requirements.

The ferment of the 'new' science and mathematics programmes did spread to tertiary levels of education and hence had some of the associated problems. Nevertheless science and mathematics at these levels could be enhanced through:

- incessant efforts to provide a wide variety of technical and vocational training in science-based fields relevant to a country's specific needs;

- attempts to establish specialised teachers' colleges of science and mathematics, with specialised courses in basic science equipment improvisation; and

- attempts to establish specialised institutes of science and technology, with specialised courses in basic science equipment production.

National universities have been the main institutional centres of scientific R & D in a majority of the developing countries of the Commonwealth. Traditionally, science departments in these universities have tended to recognise researches for higher academic achievements mainly in areas pertinent to pure science. By the same token, moves to introduce such interdisciplinary subjects as environmental science have not met with academic fervour or favour. Nor has applied research taken on a firm substratum. Traditional attitude has tended to consider academic training to be of higher socio-cultural status than dexterity-acquisition in practical technology.

All in all, science education has proved wanting in several aspects, notably science teaching and associated areas of concern. Curriculum innovation with local-flavour relevance that incorporates specialist courses on training in certain applied aspects could be a novel experience;

Secondary: the scope of science could be broadened to include industrial science (metal and wood technology, motor vehicle mechanics, etc);

Tertiary: (a) training in science teaching could include specialised training in school science apparatus improvisation;

(b) training in various skills at institutes of science and technology could include specialised training in school science equipment instrumentation and production;

University: (a) University training in the usually traditionally pure sciences could incorporate specialised complementary courses directly related to physics-based, chemistry-based, and biology-based technologies:

- metrology and associated disciplines;

- energy studies;

- environmental science studies;

- microelectronics;

(b) research programmes at universities need to match priorities pertinent to basic investigation with those for applied research in order to strike at local-flavour relevance.

5. The Socio-Cultural Dimension

The traditional 'production-line' ethos and public examination nexus are two of several factors that have contributed socio-cultural impasses to attainment of educational rationality in science teaching. Characteristically many a number of students have optioned for science as a result of nominal prestige and status ostensibly placed on science disciplines. Progress in relation to pursuit of science becomes a question not so much on learning a subject for its intrinsic-cum-aethetic merits, but rather of learning how to get a grade leading to paper qualifications. This 'production-line' ethos of education in science continually holds out to the student the importance of 'nominal change' and of 'nominal becoming' without encouraging the student to enjoy and appreciate the being of 'cognitive existence'. The result is rote learning of science, with its complement of skin-depth. In a majority of countries, the requirement of public examinations is almost inflexibly paramount with respect to assessment/evaluation procedures of student learning and teacher training at all levels of education. Efforts aimed at achieving education for scientific capability become readily vulnerable to this constraint. More so is the realisation that a given body of knowledge has to be transmitted to the learner within a designated time interval. National examination bodies, employers, parents and the public at large all continue in the effort to support this socio-cultural constraint evolved of tradition. In the ultimate, the neophyte who uses science and skills in science simply to obtain passing grades misses the affluence of concepts that are contingent to scientific insight. A cognitive style is adopted which is deficient of intellectual capability and an affective style is similarly acquired which is devoid of attitudinal profundity to science.

6. The Experimental Method

The experimental method in science has merited substantive accentuation during teacher training and also during school/college pupil/student-centred laboratory investigation. A number of areas have persistently remained generally unsatisfactory, however:

. inadequacy of trained teachers to use apparatus/equipment, however scarce;

. the inadequacy of trained teachers to teach science at secondary school level; and

. a generally ill preparation of teachers to meet the challenges of new methods in the teaching of science.

The result has probably constituted a vicious circle:

(i) science teaching with scarce apparatus/equipment results in low interest andability in science;

(ii) low interest and low ability in science leads to poor performance as a student of science or teacher-trainee in science; and

(iii) poor performance as a student of science or teacher-trainee in science leads to weak performance after qualifying and the vicious circle begins again.

The vicious circle has to be broken, if education in science is to imply education for capability in science. In particular, science teaching has to cultivate in the pupil/student a style of thought that gives him the motivation of inquiry and the skill of scientific method. Improvisation, production and importation of science teaching apparatus/equipment all have to be attempted to meet the hardware demands of the scientific method. Training and re-training of teachers have to be periodically carried out to meet the pedagogic demands of new instructional methods. New methods of student evaluation/assessment have to be introduced to reduce heavy dependence on examinations as sole evaluative mechanisms.

7. Conclusion

The re-orientation of general science education systems in developing Commonwealth countries to existing scientific capability needs involves the reformation of curricula at all levels of education, to reflect specific needs and problems of the countries themselves rather than the educational traditions of advanced countries. In the ultimate, this requires the existence in each of the countries of a national science policy and of an appropriate manpower planning in addition to general development planning. Commonwealth Science Council under the auspices of its Science Management and Organisation programme area could be catalytic in assisting member countries to enhance evaluative instruments in their R & D efforts. The Education Programme, which forms part of the Human Resources Development Group (HRDG) of the Commonwealth Secretariat, aims to assist Commonwealth member countries to share, inter alia, experiences in science teaching, technical education and teacher training at all levels of formal education. Granted that Science management work in its broadest sense includes aspects of teaching related to curriculum development, it is envisaged to foster and promote a closer collaboration between Commonwealth Science Council and the Education Programme in all activities of mutual interest. In addition, CSC could inject inputs into the activities of the Commonwealth Association of Science, Technology and Mathematics Educators (CASTME), which was born out of the need to assist Commonwealth educationalists to consider the mutual interaction of science, technology and mathematics teaching. Further afield, close collaboration with UNESCO, the Association of Commonwealth Universities and the British Council will be expedient.

The Commonwealth Secretariat is encouraging local production of science equipment as a viable alternative to extensive importation of school science equipment. This helps to alleviate the school science equipment scarcity but only in differential terms. AS a supplementary effort the Commonwealth Secretariat is exploring the feasibility of instituting a 'Commonwealth Coupon Scheme' by which means the Secretariat could accept money in the local currency of a member state wishing to purchase equipment and pay for it in the currency of the country supplying it. It is hoped such efforts could go a long way to effecting education for local scientific capability in member countries of the Commonwealth.

ASSESSMENT OF RESEARCH AND DEVELOPMENT

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(A) INTRODUCTION

1.1 An essential prerequisite for sustainable development is the sensible management both of scientific research and of technological innovation. The Expanded Programme for Scientific Cooperation of the CSC has identified promising new and rapidly advancing areas of science and science-based technology with large potential benefits for less advanced countries. The subject areas for scientific cooperation are classified in four main groups: basic resources (e g energy, agriculture, tropical forest ecology and geosciences), strategic issues (e g integrated resource management, coastal zone management and epidemiology), technical issues (e g remote sensing, genetic engineering and microelectronics) and regulatory issues (e g those raised by education, popularization, information technology). These areas are characterised by new technologies for which research is vital and by dissolution of boundaries between fields of science and between science and technology. These characteristics place important requirements upon the management and administration of scientific research. A consequential aspect of this is the growing need for less advanced countries to gain their own capabilities for carrying out objective assessments and evaluations of R&D.

1.2 Expressed in other terms, there is a need to identify the requirements for effectively executing the following processes:

- absorbing relevant scientific information which already exists and is available;
- determining what further R&D is required and how this is to be accomplished;
- generating new science and technology information;
- applying the overall s&t information results to meet local needs.

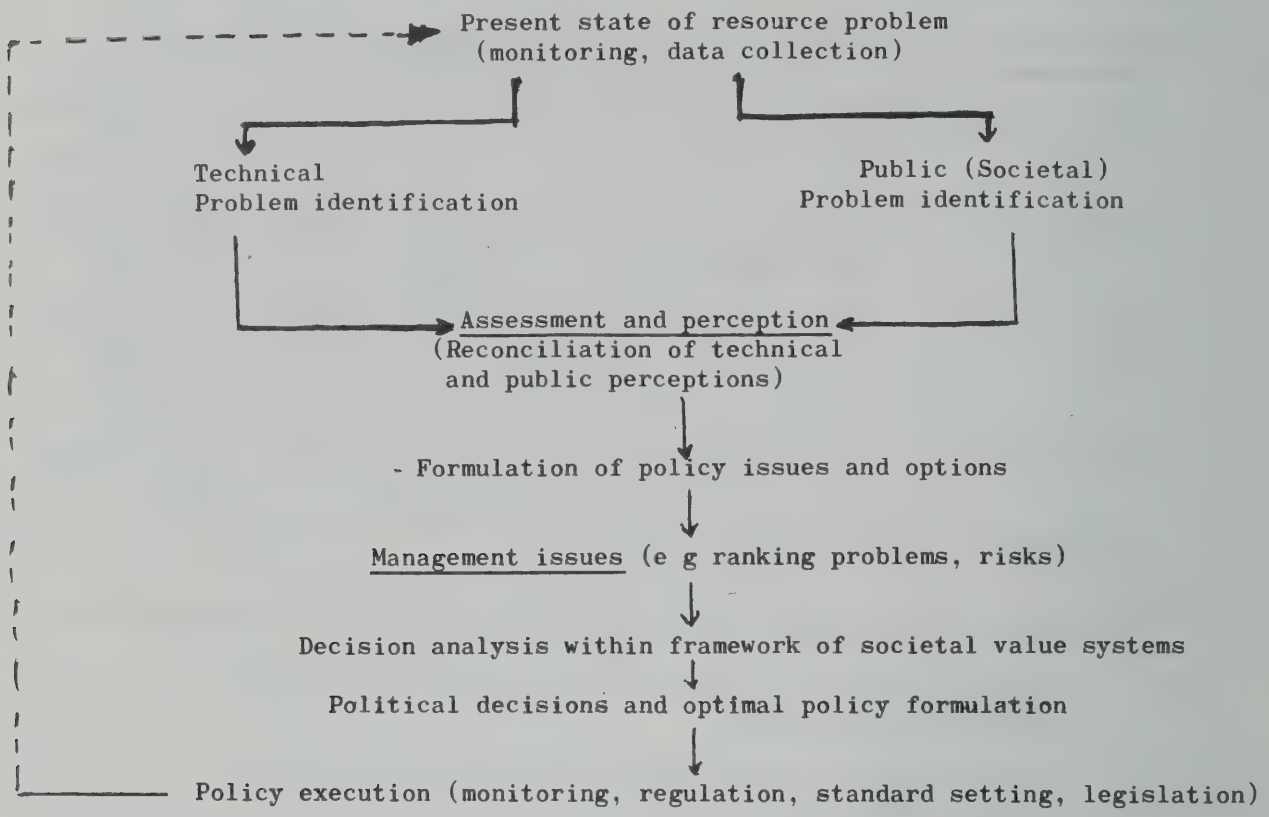
In this context the purpose of assessment and evaluation is to help in determining what additional R&D is required and in making it usable for local needs.

This document has been prepared as a general overview of the topic for the purpose of stimulating discussion about some of the main issues.

1.3 There is a need for R&D assessments using evaluation methods capable of identifying the main impacts of scientific discoveries and technological innovations on the economy, on society and on the environment. Such evaluation methods should be applicable to assessing R&D programmes both endogenous and exogenous to the given less advanced countries. Ideally these methods would enable the planning and executing of R&D programmes to be placed on a wholly rational foundation. Realistically this is not likely to be achievable, but it may nevertheless be possible to use them to provide valuable guidance for research management decisions.

1.4 An important concern is not only the carrying out of the evaluation function, or research priorities but also the integration of the evaluation activity into the processes of research and development decision making and research management, so that the results of the evaluation can be useful. A problem identified in less advanced countries is the application gap between assessment and management levels (1). See Table 1.

Table 1: Resource problems in a policy/management setting


Present state of resource problem
(monitoring, data collection)
Technical
Problem identification
Public (Societal)
Problem identification
Assessment and perception
(Reconciliation of technical
and public perceptions)
- Formulation of policy issues and options
Management issues (e g ranking problems, risks)
Decision analysis within framework of societal value systems
Political decisions and optimal policy formulation
Policy execution (monitoring, regulation, standard setting, legislation)

1.5 The CSC has had some previous experience in R&D management and administration, but R&D evaluation as a specific topic is new to it. The topic is complex. Section(B) below identified some of the potentials which evaluation offers and some of the difficulties in applying it to the main categories of research of significance to the CSC.

1.6 A clear need is perceived for the CSC to include R&D assessment and evaluation in its programme of training and studies for managers of science and technology in less advanced countries. The CSC proposals in this area may be seen as complementary to its other programmes of activity and also to the programmes of activity of other organisations (e g World Bank, IDRC) involved in assisting Commonwealth countries in the field of science and technology (2).

(B) ANALYSES AND INTERPRETATION

2. General

2.1 Selectivity among topics chosen for R&D is becoming essential for all countries, for a variety of reasons:

- large developed countries find their resources for S&T are diminishing. They have to balance this with the importance of S&T in economic growth/revival;

- smaller and less advanced countries have the need selectively to decide which sciences and technologies are most appropriate to their culture, social needs, industrial needs.

2.2 It is hard to select technologies even where they are mature enough for the economic and industrial potential to be fairly obvious. The criteria for selection are not well defined.

Science selection is even harder. Selection is mainly carried out through an academic peer review system which judges on scientific merit. But the signs are that other criteria are starting to become important (such as criteria related to technical benefit, dynamics of science, etc). In the early stages 'negative' selectivity will probably be applied, i e research funding organisations will decide not to enter or pursue certain fields of science.

Monitoring of government sponsored science and technology whether in academic or industrial environments is becoming very important. The objectives against which science is assessed are not yet clear but depend on peer review judgement. In any case, realtime programme monitoring and data collection are essential.

2.3 Less advanced countries have a special problem. In selecting the S&T they either want to do themselves, or want to 'import'; it is necessary to obtain an understanding of the potential value to the country itself(3). The problem is how to do this, what assessment criteria to adopt and how to attract able scientific minds to consider the selection problem. Conventional pressures and issues of academic prestige tend to be against this; they are rather more directed to the perpetuation of research in chosen areas.

Countries wishing to develop and extend their S&T base clearly need to select the most relevant science for their needs. They also need to establish which other countries, scientists or laboratories can help provide the expertise either collaboratively or through S&T licensing. Indicators and methodologies currently being developed (citations, patents etc) can help these decisions by giving ideas about the relative contribution to the topics as well as the strengths of people and institutions(4).

3. Some general remarks on issues in the development of assessment and evaluation capability of R&D

3.1 Despite the apparent growing need for systems of evaluation which can help choose between R&D priorities in both developed and less advanced countries and which can assist the assessment of effectiveness of research and its support, the development of evaluation methods has been slow. Terms such as "auditing", "programme monitoring","programme analysis", "policy analysis" and "costbenefit" analysis have been used synonymously with the term programme evaluation. There is also the general sense of the term meaning an overall assessment of the balance of research and technology priorities, e g between activities along the innovation spectrum (basic and applied research, development, or technology transfer).

3.2 Furthermore the method of evaluation differs according to the type of research activity being evaluated (applied or basic, short or long term), emphasis being placed on the quality of the research, on the effectivenesses of the management and organisation of a programme, on the potential impact of the results of a specific research programme or on future orientations and strategies(5).

3.3 In addition, evaluations often have to serve different clients (e g government decision makers, scientist managers) and methods must therefore reconcile different needs and perspectives:

- At policy level needs the scientific findings of the evaluation as well as the recommendations for the possible improvements in managements in management effectiveness.

- The scientific level includes not only programme management but the scientific community at large.

3.4 Evaluations have to assess the output of research taking into account conditions which may be different from those which were relevant at the time when the original objectives of the programmes were decided upon. The outputs of the research may have a social or economic impact only in the very long term, aspects which add to the difficulties of developing a systematic evaluation methodology.

3.5 In other words, the evaluation procedure adopted should be flexible to suit the particular management and organisational structures of the research institute, as well as the needs of the users. There is no single evaluation system which can be applied to all programmes. Evaluation methods need to be developed pragmatically according to the type of programme being evaluated and to the objective of the evaluation. They need to take into account the process of executing an R&D programme as well as its eventual outcome.

3.6 Different areas of evaluation should be treated separately because they involve different techniques of assessment, although they all need to interact to build up a total evaluation system. They involve different evaluation procedures and different information requirements.

3.7 Four areas of evaluation can be identified, as follows:

- evaluation of scientific and technological priorities, which takes place at a high level of generality and is dependent of the national mechanisms for the coordination of scientific research funding;

- evaluation of specific programmes and projects from inception(ex-ante) which has two aspects (i) the first requires an assessment of what the programme is designed to achieve (i e to specify objectives or to suggest quantitative indicators which can measure whether objectives have been achieved); (ii) the second aspect concerns the assessment of specific projects;

- monitoring, which should provide information on the portfolio of projects within the programme and how it is developing;

- evaluation of programmes and projects after their completion (ex-post), which is the most complex aspect of evaluation, posing administrative, data and analytical difficulties.

3.8 The administrative difficulties that arise are basically three-fold:

- It is generally recognised as preferable that ex post evaluation should be carried out by a group which is independent of the administration of the programme. This can be done by creating an in-house function devoted entirely to evaluation or by using external agencies. The problem is that, being independent, the evaluation team will not have been involved in the support programme as it unfolds and will not necessarily have had a chance to ensure that the information required for evaluation has been collected in a conveniently accessible form.

- The evaluation team, particularly in the area of R&D support, will need to contain a range of skills. As such and given the resource intensive nature of evaluation, there must be a serious commitment to the evaluation task which may not be forthcoming in times of scarce resources. This can create a chicken and egg situation since evaluation can only prove its value if sufficient resources are allocated to it.

- The timing of evaluation poses a serious problem. Sufficient time must be allowed to elapse before the programme's impact can be assessed (particularly in R&D programmes). And yet, for the results of evaluation to be used to change and refine a programme, the time lapse must not be allowed to become too great. Thus, the credibility of evaluation can always be questioned by its sceptics.

3.9 The data and analytical problems are particularly serious in the evaluation of R&D programmes. This is largely because the benefits are invariably long term, uncertain and diffused. The long-term nature of benefits makes the timing of evaluation of R&D programmes particularly critical. It also raises analytical questions about the appropriateness of using NPV or D C F discounting methods with rates of return more usually associated with low risk, short-term flows of benefits(6).

4. Uncertainties of the Process of R&D and its Application

4.1 The effective use of the assessment R&D methods depends on an understanding of some of the specific characteristics of the R&D process. There are significant uncertainties at all stages of the process of R&D and its application. At one end of the spectrum the outcome of fundamental research is uncertain in that a hypothesis may be proved or rejected, or that new fundamental knowledge may not be relevant to a practical application. At the other end of the same spectrum, the successful application and the benefits of R&D are uncertain, depending on the reaction of users and competitors, and on the social and environmental effects resulting its application - all of which are defficult to predict.

4.2 Table 2 (from an OECD Science Policy Report, 1972) attempts to present some of these implications in a schematic form through the spectrum from basic research, through development to use and policy objectives. Thus, as one moves from right to left across this spectrum towards fundamental research, the following characteristics emerge:

- the option-opening nature of the activity: in other words fundamental research is more likely to generate new approaches to existing policy objectives, or even new policy objectives, than to fit in tidily with existing objectives and technical approaches to them;

- the key uncertainties are related to scientific and technical results, their timing and their relevance to existing policy objectives;

- significant results can be achieved at relatively low costs, with some important exceptions (e g space research, high energy physics);

- the criteria for decision-making are mainly scientific quality and opportunity-oriented;

- allocation decisions are related to R&D activities only.

Whereas as one moves from left to right across the spectrum towards application, the following characteristics emerge:

- the option-choosing nature of the activity: in other words, it is likely to be related to established technical solutions in relation to established policy objectives;

- the key uncertainties are related to the use of the technology: in other words, to primarily non-technological factors;

- higher costs are required to obtain significant results,

- the criteria for decision-making are mainly related to needs; once again, mainly non-technological factors;

- allocation decisions are concerned with more than R&D activities alone.

TABLE 2

BASIC RESEARCH	EXPLORATORY RESEARCH	APPLIED RESEARCH	DEVELOPMENT	TESTING	EVALUATION	USE	POLICY OBJECTIVE
OPTION-OPENING							OPTION-CHOOSING
LOW-COST							HIGH COST
KEY UNCERTAINTIES RELATED TO SCIENTIFIC AND TECHNICAL RESULTS, THEIR RELEVANCE, AND TIME HORIZONS FOR ACHIEVING THEM				KEY UNCERTAINTIES RELATED TO THE USE OF THE TECHNOLOGY (E G REACTION OF CONSUMERS, OF COMPETITORS, OF SOCIAL AND ENVIRONMENTAL EFFECTS)			
CRITERIA FOR CHOICE LIKELY TO BE SCIENTIFIC-QUALITY - AND OPPORTUNITY-ORIENTED				CRITERIA FOR CHOICE LIKELY TO BE NEEDS-MARKET - AND COST-ORIENTED			
ALLOCATION DECISIONS CONCERN R-D RESOURCES ONLY				ALLOCATION DECISIONS CONCERNS MORE THAN R-D RESOURCES			

4.3 This framework enables some degree of classification of the advantages and drawbacks of using various analytical techniques at different stages of the R&D process. Equally important however, are its implications for the type of R&D strategy that governments should follow at various stages of the R&D process. For example, it is obvious that, as one moves across the spectrum from right to left towards fundamental research, it becomes more important to keep key options open than to choose amongst them, because technical uncertainties are still high, time horizons are long, and costs are low. But the really important objective of policy, and of any related analysis, should be to keep the key options open.

4.4 The difficult problem of policy is to decide, as one moves from left to right across the chart, to what extent and when to choose between various options. This problem is likely to be most acut when costs and/or time pressures increase more rapidly than the scientific, technical or other uncertainties are reduced.

Given stringent limitations on expenditure, the reaction of most economists and administrators is to fix objectives precisely, to plan and to forecast thoroughly, and to eliminate what looks like duplication and overlap. But when uncertainties are high, can objectives be fixed accurately, can forecasting be precise, and is the elimination of duplication and overlap necessarily wise?

4.5 The table suggests also that the role of analytical techniques will be in planning and controlling R&D activities with great precision and over relatively extended periods, and more in making broad assessments of opportunities and needs, in identifying key parameters, in making explicit key uncertainties, in suggesting strategies of action which take into account these uncertainties and (hopefully) reduce them, and in developing a framework within which the implications of unforeseen events can be accommodated.

4.6 In addition to its uncertainty, R&D has other characteristics which differentiate it from other "investments" or expenditure: they relate to the valuation of its output, and to the fact that this output can be re-used continously. The "output" of R&D activities is knowledge or "information". In most cases, this information has some monetary or other value, only through combination with other information or through combination with other types of investments. Hence the difficulties, at one level, of isolating the contribution of "technological progress" to economic growth.

But perhaps more important is the difficulty of measuring the "output" of R&D at the level of a project of programme and the consequent danger of inadequate analysis of their contribution to policy objectives and danger of ignoring the particularities of the R&D process.

4.7 Given the importance of the integration of the results of R&D with other knowledge and other information, social value of the output of R&D largely depends on the effectiveness with which it is diffused. This is done through the process of publication of scientific papers and of technical journals, but empirical studies have shown the key importance in the diffusion process of personal contacts (between scientists, between engineers, amongst scientists, engineers and users, training and educational), and of personal mobility (both in and between institutions). Thus, any analysis of the potential benefits of R&D programmes should ideally take into account the degree to which the institutional framework and managerial practice facilitate such contact and mobility.

5. Proposed areas of future activities:

5.1 The considerations outlined in previous sections make the application of evaluation methods a multivalued problem emphasising the complexity of the task. Consequently CSC is considering initiating a series of activities training workshops, seminars, publications creating networks to assist its members in the appropriate use of evaluations. These will

assist scientists/managers to develop their own capability in choosing and applying evaluation methods rather than providing them with recipes for how and when to perform a given type of analysis. The general objectives of the activities in this area will be:

- to develop a common approach to the role and use of R&D evaluation methods taking into account differences between the research aims of different Commonwealth countries;

- to identify gaps among appropriate methods of evaluation in relation to new types of research activity.

5.2 The main issues for debate concerning R&D evaluation would be related to:

- general description of underlying principles of evaluation;
- users of evaluation;
- objectives of evaluation;
- procedures and criteria;
- selection of evaluations (choices of experts);
- timing of evaluations;
- use of evaluation findings;
- institutionalisation of evaluation capability.

5.3 Evaluation is not a recognised professional activity and for that reason, it is useful to have some kind of initial evaluation guidelines, perhaps providing handbook (or compendium) for the potential users of the techniques. The handbook could provide a review of the present evaluation techniques as well as identifying modifications required as a result of specific needs highlighted through discussions with potential users.

5.4 The development and use of Intelligent Knowledge Based Systems as an aid to various aspects of the management of science in less advanced countries would be another further activity. It appears possible to embody science management tools (e g assessment techniques) in expert system programmes which could be used by the scientists themselves as pointers to those fields where scientific activity could be most productive both in scientific and social terms (7).

5.5 Other areas of analytical activity related to evaluation/assessment R&D to be developed are the following:

- Integrated impact assessments, Science & Technology Indicators, particularly those related to the assessment of quality of science in less advanced countries (i e process indicators);
- Interdisciplinary research and its implications for management of science as part of Science and Technology management issues;
- Analysis of regulatory science, where three distinctive analytical activities are involved, (1) science assessments which aggregate the results of scientific research and evaluate the seriousness of health, safety, and environmental risks, (ii) economic/social impact analyses which evaluate the costs and benefits of regulatory action, & (iii) decision analysis which brings together all relevant information scientific, economic social, legal, political and identifies options for action and their advantages and disadvantages.

(C) CONCLUSIONS

6.1 The CSC's Expanded Programme for Scientific Cooperation has identified promising new and rapidly advancing areas of science and science-based technology with large potential benefits for developing countries. The characteristics of these new areas place important requirements upon the management and administration of scientific research. There is a growing need for less advanced countries to gain their own capabilities for carrying out objective assessments/evaluations of R&D.

6.2 Such assessments/evaluations need to utilise methods capable of identifying the main impacts of scientific discoveries/technological innovations on the economy, on society and on the environment. An important concern is only the carrying out of the evaluation function, but also its integration into the processes of decision making and research management, so that the results of the evaluation can be useful.

6.3 The CSC has had extensive previous involvement in R&D management and administration, but R&D evaluation, which is a complex topic, is new to it. The potential benefits offered by R&D evaluation include the following:

- Selectivity among topics chosen for R&D, enabling limited financial and trained manpower resources to be more effectively used.

- At the policy level, identification of the most important science-based options before a country and ensuring that these are kept open.

6.4 Some difficulties in applying R&D evaluation and the complexities of the topic include the following:

(i) Existing systems for selecting science and technology topics may not be adequate and may require extensive modification of selection criteria.

(ii) There are informational problems. Developing countries need to be aware of the options open to them and to be able to establish which other countries, scientists or laboratories can help provide relevant expertise.

(iii) There are various types of R&D evaluation, all interacting, but each with its own contribution to make and its own set of evaluation techniques. A convenient subdivision is as follows:

- Evaluation of scientific and technological priorities;
- Ex-ante evaluation of specific programmes and projects;
- Monitoring during the course of a programme or project;
- Ex-post evaluation;

(iv) There are uncertainties in R&D evaluation which can be minimised but may still remain substantial. Budgetary limitations may force planning decisions which fix objectives precisely even though the results of evaluation remain equivocal. The credibility of R&D evaluation is strained in such circumstances.

6.5 A clear need is perceived for the CSC to include R&D assessment/evaluation in its programme of training and studies for managers of science and technology in developing countries. Outline proposals for this are presented. The proposals may be seen as complementary to other CSC programmes of activity and also to the programmes of activity of other organisations (e g World Bank, IDRC) involved in assisting Commonwealth countries in the field of science and technology.

6.6 This document has been prepared as a general overview of R&D assessment/ evaluation for the purpose of stimulating discussion for the Expert Group meeting, about some of the main issues.

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